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# Optimal Labor Contracts May Exhibit Wage Fluctuations due to Wage Discrimination

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**ABSTRACT.** – Consider a labor market where the parties are able to write contracts contingent on the state of demand and productivity. If it is realistically assumed that the workers differ wrt. their reservation wages, then it becomes a natural presumption that firms on the market will offer several alternative contracts instead of just one and let workers choose between them. This may give a gain from wage discrimination. In a specific model of a labor market with one firm and two types of workers we show that it is indeed optimal for the firm to offer two different contracts. Further, we state plausible conditions in terms of the workers' attitudes towards risk which imply that optimal pairs of contracts feature wage fluctuations over the cycle on one of the contracts. This result is somewhat in contrast to a standard (interpretation of a) result from the theory of labor contracts.

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## Les contrats de travail optimaux peuvent illustrer des fluctuations salariales dues à des discriminations salariales

**RÉSUMÉ.** – Le cadre de cette étude est un marché de travail spécifique où les partenaires ont la possibilité de conclure un contrat de travail conditionné par d'une part la demande prévue et d'autre part la productivité de l'entreprise.

Suivant le « salaire de réserve », élevé ou bas, les salariés sont divisés en deux groupes. Il apparaît donc optimal pour l'entreprise de proposer deux contrats distincts.

Nous établissons des conditons vraisemblables concernant l'attitude des salariés vis-à-vis du risque, qui impliquent que des paires optimales de contrats illustre les fluctuations de salaire durant le cycle d'un des contrats.

Ce résultat est légèrement en contraste avec la théorie habituelle des contrats de travail.

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# 1 Introduction

In the theory of optimal labor contracts there is a very basic and standard result which can be given the following formulation:

Consider a risk neutral – expected profit maximizing – firm subject to revenue fluctuations arising from demand or productivity shocks. The firm is confronted with a number – sometimes represented by one – of risk averse workers from whom it buys labor. Trade in labor can take place before realization of the revenue shock is known and the firm is assumed to be able to offer to workers a conditional contract specifying wage and employment in each state, that is, for each possible realization of the revenue shock.

Each worker decides whether to sign up for the contract or not; if he does, he must accept the wage and employment situation that arises when the shock is observed. An optimal contract maximizes expected profit [1]. Under quite general conditions the optimal contract is such that the wage is the same in all states while employment differs across states. This result conforms with the empirical stylized fact that employment is more volatile than wages over the business cycle. The intuition for this is that the risk neutral firm insures the risk averse workers, which explains the rigid wages, while the employment fluctuations give productive efficiency. For early formulations see AZARIADIS [1975], BAILY [1974], and GORDON [1974]; a version of the result is given in Section 3 below. For an overview see HART [1983].

There may be many reasons, and in the theory of labor contracts many reasons have been given, why optimal labor contracts do not exhibit completely rigid wages after all. Nevertheless this potential explanation of rigid wages and volatile empolyment over the cycle seems to have crystalized as one of labor contract theory's major contributions. This is, for instance, the view taken in the recent macro text book, BLANCHARD and FISHER [1989]. In this paper we give a new reason why optimal labor contracts may very well exhibit wage fluctuations.

We stick closely to the framework above with a risk neutral firm etc. but add one very realistic feature: Workers have different opportunities outside the considered labor market, that is, they have different reservation wages and each individual worker's reservation wage is his private information whereas the firm only knows the distribution over reservation wages; there is asymmetric information wrt. worker's reservation wages. In effect we assume that there are *two* types of workers.

1. Information wrt. the revenue shock may be symmetric – both workers and firm observe its realization when it takes place – or asymmetric – only the firm observes the realization. In the latter case some additional incentive compatibility constraints must be included in the definition of an optimal contract. In this paper we assume symmetric information wrt. the revenue shock throughout.

In this case it is a natural idea that the firm will offer two different contracts to the workers instead of just one. Contracts are, of course, complicated objects because they condition on future events. The complicated step, however, is not going from one to two but rather to operate conditional contracts at all. It is therefore quite in the spirit of the theory of labor contracts to analyze the situation where the firm may, if it wishes, offer two different contracts. The potential gain from this lies in the possibility of conducting wage discrimination – or wage differentiation as some may prefer to call it.

This calls for a characterization of optimal *pairs* (or, in general, sets) of labor contracts when workers are different as described, which is indeed an ongoing research project of ours [2]. In the present paper we show that often the firm should indeed offer two contracts and not just one; the wage discrimination effect is important. One contract should be designed to attract the low reservation wage – the « weak » – workers, while the other should be designed to attract the « strong » workers. On the contract of the weak workers there are no fluctuations in wages over the cycle, thus conforming with the standard result. Our main message is that on the strong workers' contract, which happens to have higher average wage than the weak workers', there may very well be wage fluctuations. The basic condition sufficient for this is that the weak workers should be sufficiently much more risk averse than the strong workers. Intuition for this result is provided in the concluding remarks after presentation of our formal results.

If one accepts that in real life workers are different wrt. outside opportunities or « strength » and that it is natural to assume that a firm which can operate one contract can also operate several, then the empiricaly testable hypothesis coming out of contract theory is not necessarily that wages *for all workers* are rigid over the cycle, but could as well be that *for each type of labor* one should expect to see more volatility in wages for workers with high average wages than for workers with low average wages. Some empirical observations conform with this. Many firms have bonus systems which give some additional payment if the firm performed well during a specific year, say. It is our impression that for workers with relatively modest average wages such systems are of limited importance or completely absent, while for workers with higher incomes they are more important. Such bonus systems could very well be seen as a way of implementing the kind of optimal sets of contracts described in the paper [3]. Note that we are here viewing our main result not so much as explaining

2. What comes closest to this project in the literature is, to our knowledge, MOORE [1986]. He analyses a model where there is also some asymmetric information wrt. workers' reservation wages. In his work, however, ex ante reservation wages are unknown to everybody (including workers), whereas ex post only the individual worker learns his reservation wage. MOORE characterizes optimal contracts which give workers insurance over the reservation wages they may end up with. His results are therefore of a different nature than ours.

3. Bonus systems are sometimes explained with reference to individual work incentives. Such an explanation is not convincing if the bonus system in question covers many workers and the bonus is tied to the overall performance of the firm. Each individual worker's influence on the firm's performance as a whole is small.

very general macroeconomic phenomena but rather as explaining particular phenomena on certain labor markets. We think this is in good accordance with the competely *partial* equilibrium approach taken here and in contract theory in general.

# 2 A Labor Market

We consider a simple labor market with one firm and a large number of workers. The firm has the revenue function $zT(l)$, where $l$ is labor input, $T(0) = 0$, $T$ is twice differentiable with $T' > 0$ and $T'' < 0$, and $z$ is a random shock which attains the two values $z_H$ and $z_L$, $z_H > z_L$, with probabilities $\psi_H > 0$ and $\psi_L > 0$ respectively, $\psi_H + \psi_L = 1$. The firm is an expected profit maximizer and thus risk neutral.

Each worker is equipped with one unit of « time » that can, potentially, be used as labor power in the firm. All workers are equally productive. The workers and the firm are all equally informed about the revenue shock; labor is traded before the realization of $z$ is known, but everybody knows its distribution. When $z$ is realized everybody observes it, so it is possible to write a contract contingent on it.

Each worker has the von NEUMANN-MORGENSTERN utility function $U(w - R)$, where $w$ is the wage rate obtained by the worker for his one unit of labor, and $R$ is the reservation wage of the worker. All workers have the same function $U$, but may differ wrt. reservation wages. We assume that $U(0) = 0 =$ the utility from not being hired by the firm, and further that $U' > 0$, $U'' < 0$.

Workers are assumed to be different; they have different, privately observed, reservation wages. Measuring labor in terms of fractions of the total work force, we assume that there are $A$ workers with reservation wage $R_1$, and $(1-A)$ workers with reservation wage $R_2$, where $R_2 > R_1 > 0$, and $0 < A < 1$. The firm cannot identify each individual worker's reservation wage, but knows the distribution, so there is asymmetric information with respect to reservation wages.

We now impose a number of assumptions on the elements of this labor market. These will enable us to illustrate our main point in a simple way: That optimal labor contracts may very well involve wage fluctuations solely due to wage discrimination. There is no doubt that this phenomenon is more general than the following assumptions may indicate.

A1. $z_H T'(1) > R_2$.

A2. $z_L T'(1) < R_2 < z_L T'(A)$. Or expressed differently:

With $\bar{l} \equiv \underset{l \geq 0}{\operatorname{argmax}} \ (z_L T(l) - R_2 l)$, we have $A < \bar{l} < 1$.

If the firm were to hire labor power at a given wage rate *after* realization of the shock $z$, then, from A1, it would hire all workers in the high state, even if the wage were equal to the high reservation wage. In the low state it would, still at the high reservation wage, hire between $A$ and all workers, A2.

A3. $z_L T'(1-A) > R_2$,

which follows from A2 if $A \geq \frac{1}{2}$.

A4. $z_H T'(1) > z_L T'(A)$,

essentially saying that the shock $z$ is more important for marginal revenue than employment being « full » or below full.

A5. There is an employment level $l'$, $A < l' < \bar{l}$,

such that, $\psi_L [z_L T'(l') - R_2](l' - A) > A(R_2 - R_1)$.

This is an assumption of a *strong* incentive for the firm to hire more than just the $A$ low reservation wage workers, even stronger than the $z_L T'(A) > R_2$ part of A2, which is, of course, implied by A5. An example fulfilling A1 – A5 is: $T(l) = l^{1/2}$, $z_H = 1.5$, $z_L = 1$, $\psi_H = \psi_L = 0.5$, $R_1 = 0.5$, $R_2 = 0.54$, $A = \frac{1}{3}$.

# 3 One Contract – A Traditional Contract Theory View

As said, labor is traded before the realization of $z$ is known. Further, the firm has all the market power and is able to dictate the conditions under which labor is traded. Instead of just setting a wage rate at which it will buy labor from those workers who want to sell, the firm offers a conditional contract

$$c \equiv (w_H, \lambda_H, w_L, \lambda_L) \in C \equiv \mathbb{R}_+ \times [0, 1] \times \mathbb{R}_+ \times [0, 1],$$

where $w_i$ is the wage if state $i$ occurs, $i = H, L$, and $\lambda_i$ is the fraction of workers signing up for the contract that will *not* be employed, and not be paid, if state $i$ occurs, while the fraction $(1 - \lambda_i)$ will be employed in state $i$. Thus $\lambda_i$ is the rate of unemployment in state $i$.

Notice that we do not allow contracts to include unemployment benefits paid by the firm. This is because such contracts are seldom seen in the real world. Publicly paid unemployment benefit can be interpreted as a part of $R$.

Each worker decides individually whether to supply his one unit of labor under the conditions of $c$ or not. If his reservation wage is $R$, his expected utility of signing up is

$$V(c, R) \equiv \psi_H (1 - \lambda_H) U(w_H - R) + \psi_L (1 - \lambda_L) U(w_L - R).$$

We assume that a worker who has signed a contract is compelled to fulfill it. This means that he may in one of the states end up working at a wage below $R$, so he would have preferred not to work. In this sense there is involuntary retention. One may wonder whether the worker will not quit in this situation. Although it is not modeled explicitly, we view the relationship between the firm and its workers as an ongoing one. A worker accepts a bad period, knowing that the future will bring some good periods. Therefore the only relevant restriction on the contract is that his expected utility is positive.

Define the reservation wage $\rho(c)$ as the reservation wage of a worker who is indifferent between signing up and not, *i.e.*,

$$V(c, \rho(c)) = 0.$$

Provided that either $\lambda_H < 1$ or $\lambda_L < 1$, we have that $V(c, R) < 0$ if $R > \rho(c)$, and $V(c, R) > 0$ if $R < \rho(c)$. Given a contract $c$, we can find the labor supply, that is, the number of workers signing the contract. If $\rho(c) < R_1$, no workers sign up, if $R_1 \le \rho(c) < R_2$, $A$ workers sign up; and if $R_2 \le \rho(c)$, all workers sign up.

Notice that if $w_H = w_L = w$, then $\rho(c) = w$, irrespective of $\lambda_H$, $\lambda_L$ as long as either $\lambda_H < 1$ or $\lambda_L < 1$. With labor supply as described, we can find the firm's expected profit as a function of the contract $c$,

$$\pi(c) \equiv \begin{cases} 0 \quad \text{if} \quad \rho(c) < R_1 \\ \psi_H\left[z_H T\left((1-\lambda_H)A\right) - w_H(1-\lambda_H)A\right] \\ \qquad + \psi_L\left[z_L T\left((1-\lambda_L)A\right) - w_L(1-\lambda_L)A\right] \\ \text{if} \quad R_1 \le \rho(c^1) < R_2 \\ \psi_H\left[z_H T(1-\lambda_H) - w_H(1-\lambda_H)\right] \\ \qquad + \psi_L\left[z_L T(1-\lambda_L) - w_L(1-\lambda_L)\right] \\ \text{if} \quad R_2 \le \rho(c) \end{cases}$$

An optimal contract for the firm solves

$$\text{Max}\, \pi(c), \quad \text{sub}\, c \in C.$$

THEOREM 1: There exists an optimal contract. For almost all parameter constellations it is unique and is either $c_1 \equiv (R_1, 0, R_1, 0)$, or $c_2 \equiv (R_2, 0, R_2, \lambda_L)$, where $1 - \lambda_L = \bar{l}$.

*Proof*: Since $\pi$ is a continuous function and $C$ can be made compact an optimal contract exists. We will prove the rest of the Theorem by a series of claims. Let $c = (w_H, \lambda_H, w_L, \lambda_L)$ be an optimal contract.

CLAIM 1: $\lambda_H < 1$ or $\lambda_L < 1$, and furthermore $\rho(c) = R_1$, or $\rho(c) = R_2$.

If $\lambda_H = \lambda_L = 1$, or $\rho(c) < R_1$, then $\pi(c) = 0$, which contradicts that $c$ is optimal since $\pi(R_1, 0, R_1, 0) > 0$. If $R_1 < \rho(c) < R_2$ (or $\rho(c) > R_2$), then one can lower $w_H$ and $w_L$ slightly, still keep $\rho > R_1$ ($\rho > R_2$), and achieve a larger expected profit. □

CLAIM 2: $\lambda_H < 1$ and $\lambda_L < 1$.

If $\lambda_L = 1$, then (by Claim 1), $\lambda_H < 1$. Change $c = (w_H, \lambda_H, w_L, 1)$ to $c' = (w_H, \lambda_H, w_H, 1)$. Then $\rho(c) = \rho(c') = w_H$, and $\pi(c) = \pi(c')$. From Claim 1 it follows that $w_H = R_1$, or $w_H = R_2$. Now, change $c'$ by lowering $\lambda_L$ slightly from 1. This does not change $\rho$, so the same number of workers sign up ($A$ if $w_H = R_1$, 1 if $w_H = R_2$). Employment in state $H$ is unchanged, and employment in state $L$ is increased from zero at the wage rate $w_H \leq R_2$. This increases expected profit since $z_L T'(0) > z_L T'(A) > R_2$, by A2. Thus $c$ cannot be optimal and $\lambda_L < 1$. In a similar way one shows that $\lambda_H < 1$. $\square$

CLAIM 3: $w_H = w_L \equiv w$.

Assume that $w_H \neq w_L$. Define the average wage rate paid on $c$,

$$\hat{w} \equiv \frac{\psi_H (1 - \lambda_H)}{\psi_H (1 - \lambda_H) + \psi_L (1 - \lambda_L)} w_H + \frac{\psi_L (1 - \lambda_L)}{\psi_H (1 - \lambda_H) + \psi_L (1 - \lambda_L)} w_L.$$

Look at the contract $\hat{c} \equiv (\hat{w}, \lambda_H, \hat{w}, \lambda_L)$. Since $U$ is concave, and $\lambda_H < 1$ and $\lambda_L < 1$ (from Claim 2), $V(\hat{c}, R) > V(c, R)$ for all $R$, implying that $\rho(\hat{c}) > \rho(c)$. Then there is a contract $c'' = (w'', \lambda_H, w'', \lambda_L)$, where $w'' < \hat{w}$, and $\rho(c'') = \rho(c)$. The expected wage bill on $c''$ is lower than on $c$, while employment in each state is the same on $c$ and $c''$, and thus $\pi(c'') > \pi(c)$, so $c$ is not an optimal contract. $\square$

Claims 1 and 3 imply that $\rho(c) = w = R_1$ or $R_2$. So, either $c = (R_1, \lambda_H, R_1, \lambda_L)$, or $c = (R_2, \lambda_H, R_2, \lambda_L)$. If $c = (R_1, \lambda_H, R_1, \lambda_L)$, then A2 implies that $c = (R_1, 0, R_1, 0)$. In the other case A1 and A2 imply that $c = (R_2, 0, R_2, 1 - \bar{l})$. An optimal contract is just a best contract among these two possibilities, and only for very special parameter values the expected profit is the same in the two cases. $\square$

The interesting case is where the contract is of type $c_2$ of Theorem 1, *i.e.*, $\pi(c_2) > \pi(c_1)$, which is equivalent to

A6. $$\psi_H (z_H T(1) - R_2) + \psi_L (z_L T(\bar{l}) - R_2) > \psi_H (z_H T(A) - AR_1) + \psi_L (z_L T(A) - AR_1).$$

In the sequel, we assume A6 (the example given in Section 2 indeed fulfills all of A1–A6). This means that for the single contract case the standard result holds; the optimal contract involves no fluctuations in wages over the cycle, but it does involve fluctuations in employment. The intuitive explanation of the rigid wage is that the risk neutral firm offers insurance to the risk averse workers. The employment fluctuations ensure productive efficiency.

# 4 An Alternative View: Two Contracts

Since there are two different types of workers, it is a natural presumption that the firm will be able to do better by offering two contracts rather than one. Hence, in this section we consider the case where the firm, a priori, offers two alternative contracts $c^1 = (w_H^1,\ \lambda_H^1,\ w_L^1,\ \lambda_L^1)$ and $c^2 = (w_H^2,\ \lambda_H^2,\ w_L^2,\ \lambda_L^2)$.

Each worker decides whether to supply his one unit of labor on contract $c^1$ or on contract $c^2$, or whether he prefers not to supply labor at all. If his reservation wage is $R$, he signs the contract with the highest $V\,(c,\ R)$, provided this is positive. Otherwise he signs no contract. We will call a contract active if some workers sign it, and it has positive employment in at least one state (not both its $\lambda$'s are one).

CLAIM 4: The firm can make more expected profit by operating two active (and, of course, different) contracts than by operating just one.

*Proof*: Let $w^1 < R_1$, and let $c^1 \equiv (w^1,\ 0,\ w^1,\ 0)$. Then $V\,(c^1,\ R_1) < 0$, so $c^1$ is not active. From Theorem 1 then, the best $c^2$ is $c^2 = (R_2,\ 0,\ R_2,\ 1-\bar{l})$, where $A < \bar{l} < 1$. Now, change $c^2$ to get the contract $\overline{c}^2 = (R_2,\ 0,\ R_2,\ (1-\bar{l})/(1-A))$, and change $c^1$ to $\overline{c}^1 = (\overline{w}^1,\ 0,\ \overline{w}^1,\ 0)$, where $V\,(\overline{c}^1,\ R_1) = V\,(\overline{c}^2,\ R_1)$. This happens for $R_1 < \overline{w}^1 < R_2$. Now $A$ workers will sign $\overline{c}^1$, while $(1-A)$ sign $\overline{c}^2$. For both contract pairs $(c^1,\ c^2)$ and $(\overline{c}^1,\ \overline{c}^2)$, employment in state $H$ is 1, and employment in state $L$ is $\bar{l}$. But on the pair $(\overline{c}^1,\ \overline{c}^2)$, $A$ workers are only paid $\overline{w}_1 < R_2$. Therefore $(\overline{c}^1,\ \overline{c}^2)$ gives more expected profit. □

It is without loss of generality to assume that the contracts $c^1$ and $c^2$ will be arranged such that the workers with reservation wage $R_1$ have incentive to sign $c^1$, while those with $R_2$ sign $c^2$. This requires the following individual rationality (IR), and incentive compatibility (IC) constraints, for $R_1$- and $R_2$-workers respectively.

$$(1) \qquad V\,(c^1,\ R_1) \geq 0, \qquad \text{and} \qquad V\,(c^1,\ R_1) \geq V\,(c^2,\ R_1).$$

$$(2) \qquad V\,(c^2,\ R_2) \geq 0, \qquad \text{and} \qquad V\,(c^2,\ R_2) \geq V\,(c^1,\ R_2).$$

Considering only contracts fulfilling (1) and (2), the expected profit of the firm is,

$$\begin{aligned}\overline{\pi}\,(c^1,\ c^2) \equiv \psi_H\,[z_H T\,(\,(1-\lambda_H^1)\,A + \,(1-\lambda_H^2)\,(1-A))\\ - w_H^1\,\,(1-\lambda_H^1)\,A - w_H^2\,\,(1-\lambda_H^2)\,(1-A)]\\ +\psi_L\,[z_L T\,(\,(1-\lambda_L^1)\,A + \,(1-\lambda_L^2)\,(1-A))\\ - w_L^1\,\,(1-\lambda_L^1)\,A - w_L^2\,\,(1-\lambda_L^2)\,(1-A)].\end{aligned}$$

An *optimal pair of contracts* is $(c^1,\ c^2)$, that solves,

$$\text{Max}\,\tilde{\pi}\,(c^1,\ c^2), \quad \text{sub}\,c^1,\ c^2 \in C, \quad (1)\,\text{and}\,(2).$$

CLAIM 5: An optimal pair of contracts exists. For an optimal pair,

$$V\,(c^1,\ R_1) = V\,(c^2,\ R_1) > 0,$$
$$V\,(c^2,\ R_2) = 0 > V\,(c^1,\ R_2),$$
$$w_H^1 = w_L^1 \equiv w^1, \qquad R_1 < w^1 < R_2, \quad \text{and} \quad \lambda_H^1 = 0.$$
$$\hat{w}^2 \equiv \frac{\psi_H\,(1-\lambda_H^2)\,w_H^2 + \psi_L\,(1-\lambda_L^2)\,w_L^2}{\psi_H\,(1-\lambda_H^2) + \psi_L\,(1-\lambda_L^2)} \geq R_2$$

*Proof*: 1. The maximization above is of a continuous function over a set that can be compactified, so an optimal pair of contracts exists.

2. Assume $V(c^1, R_1) > V(c^2, R_1)$. Then, since $V(c^2, R_1) > V(c^2, R_2) \geq 0$, we also have $V(c^1, R_1) > 0$. Now both $w_H^1$ and $w_L^1$ can be lowered and still have all of the IR- and IC-constraints of (1) and (2) fulfilled. Since both contracts are active this gives higher expected profit. Thus in optimum, $V(c^1, R_1) = V(c^2, R_1) > 0$.

3. Let $\hat{w}^i \equiv \dfrac{\psi_H (1-\lambda_H^i) w_H^i + \psi_L (1-\lambda_L^i) w_L^i}{\psi_H (1-\lambda_H^i) + \psi_L (1-\lambda_L^i)}$, the expected wage on contract $c^i$. By definition of $\rho(c^i)$,

$$\begin{aligned}&\psi_H (1-\lambda_H^i) U(w_H^i - \rho(c^i)) + \psi_L (1-\lambda_L^i) U(w_L^i - \rho(c^i)) = 0\\ &\quad \leq (\psi_H (1-\lambda_H^i) + \psi_L ((1-\lambda_L^i)) U(\hat{w}^i - \rho(c^i)),\end{aligned}$$

since $U$ is strictly concave, so $\rho(c^i) \leq \hat{w}^i$. Furthermore, the inequality is strict if $w_H^i \neq w_L^i$.

4. Now, we show that $V(c^1, R_2) < 0$. Assume this is not the case. Then $V(c^2, R_2) \geq V(c^1, R_2) \geq 0$, implying that $\rho(c^2) \geq R_2$ and $\rho(c^1) \geq R_2$. By 3. this means that $\hat{w}^2 \geq R_2$ and $\hat{w}^1 \geq R_2$. One of these inequalities is strict unless $w_H^2 = w_L^2 = w_H^1 = w_L^1 = R_2$. In this case there is essentially only one contract, and this is not optimal cf. Claim 4. Say $\hat{w}^2 > R_2$. Then the expected profit can be increased by employing the same number of workers as on $c^1$ and $c^2$ all at the wage $R_2$. This proves that $V(c^1, R_2) < 0$.

5. If $V(c^2, R_2) > 0$, then the wages on $c^2$ can be lowered slightly without violating (2) or (1). Therefore $V(c^2, R_2) = 0$, $\rho(c^2) = R_2$. But then $\hat{w}^2 \geq R_2$, since $\hat{w}^2 \geq \rho(c^2)$ from 3.

6. If $w_H^1 \neq w_L^1$, then decrease $w_H^1$ slightly and increase $w_L^1$ a little such that $\hat{w}^1$ is unchanged. This increases $V(c^1, R_1)$, and hence the wage can be lowered in both states while the IR- and IC-constraints (1) and (2) are still fulfilled. This increases expected profit, and therefore $w_H^1 = w_L^1$.

7. Since $w_H^1 = w_L^1 = w^1$, $\rho(c^1) = w^1$. As $V(c^1, R_2) < 0 = V(c^1, \rho(c^1)) = V(c^1, w^1)$, and $V$ is decreasing in $R$, we have $w^1 < R_2$. From $V(c^1, R_1) \geq V(c^2, R_1) > V(c^2, R_2) = 0 = V(c^1, \rho(c^1)) = V(c^1, w^1)$ it follows that $R_1 < w^1$.

8. We show that $\lambda_H^1 = 0$. If $\lambda_H^1 > 0$, then lower it a little. This can be done without violating any of the IR- or IC-constraints. Thus all $R_1$-workers will still go for $c^1$, and all $R_2$-workers will go for $c^2$. All that has happened is that employment in state $H$ has increased at the wage rate $w^1 < R_2$. Since from A1, $z_H T'(l) > R_2$ for all $l \leq 1$, this increases expected profit. $\square$

To prove the limited result we are interested in here – that optimal *pairs* of contracts may very well involve wage fluctuations – we will proceed as follows. We first impose as a *further restriction* that (also) contract $c^2$ has no wage fluctuations, that is,

$$w_H^2 = w_L^2. \tag{3}$$

Then we define a *restricted optimum* as a pair of contracts solving,

$$\text{Max}\, \overline{\pi}(c^1, c^2), \quad \text{sub}\, c^1, c^2 \in C, (1), (2) \text{ and } (3),$$

and characterize the restricted optimum rather closely in Claims 6 and 7 below. Finally, we show that under certain (not implausible) conditions the firm can make more expected profit than in the restricted optimum, which is the best it can do *without* creating wage fluctuations. It then follows that for an optimal pair of contracts there must be fluctuations in wages over the cycle on contract $c^2$.

CLAIM 6: A restricted optimum exists. Any restricted optimum $(c^{1*},\, c^{2*})$ is of the form,

$$c^{1*} = (w^{1*},\, 0,\, w^{1*},\, 0), \quad \textit{and} \quad c^{2*} = (R_2,\, 0,\, R_2,\, \lambda^*),$$

where $R_1 < w^{1*} < R_2$, and $0 < \lambda^* < 1$, and $(w^{1*},\, \lambda^*)$ solves,

$$U\,(w^1 - R_1) = [\psi_H + \psi_L\,(1-\lambda)]\, U\,(R_2 - R_1). \tag{4}$$

*Proof*: 1. First note that Claims 4 and 5 also hold for restricted optima. In fact, the contracts considered in the proof of Claim 4 were of the restricted form. Existence and $V\,(c^1,\, R_1) = V\,(c^2,\, R_1) > 0$, $V\,(c^2,\, R_2) = 0 > V\,(c^1,\, R_2)$, $w_H^1 = w_L^1 = w^1$ and $\lambda_H^1 = 0$ can be proved as in the proof of Claim 5.

2. For restricted pairs $(c^1,\, c^2)$, where $w_H^1 = w_L^1 \equiv w^1$, *and* $w_H^2 = w_L^2 \equiv w^2$, the expected utility functions are of a particularly simple form,

$$V\,(c^1,\, R) = [\psi_H\,(1-\lambda_H^1) + \psi_L\,(1-\lambda_L^1)]\, U\,(w^1 - R),$$

and

$$V\,(c^2,\, R) = [\psi_H\,(1-\lambda_H^2) + \psi_L\,(1-\lambda_L^2)]\, U\,(w^2 - R),$$

and thus $\rho\,(c^2) = w^1$, $\rho\,(c^2) = w^2$. Since $V\,(c^2,\, R_2) = 0$, this requires $w^2 = R_2$. The IC-constraint of (1) then implies that either $\lambda_H^2 > 0$ or $\lambda_L^2 > 0$.

3. We show that $\lambda_L^1 = 0$. Assume that $\lambda_L^1 > 0$. If further $\lambda_L^2 < 1$, then $\lambda_L^1$ can be decreased a little, and $\lambda_L^2$ increased a little such that the IC-conditions are still fulfilled, and such that employment is unchanged in state $L$ (all that has happened is that workers have been moved from $c^2$ to $c^1$). Since $w^1 < w^2 = R_2$, this improves expected profit. If $\lambda_L^2 = 1$, then just decrease $\lambda_L^1$ a little which does not violate any IC-constraint. Employment in state $L$ is less than $A$ as $\lambda_L^2 = 1$, so now $z_L T'\,(A) > R_2$ (from A2), and $w^1 < R_2$, ensures that expected profit is increased.

4. We show that $\lambda_L^2 < 1$. Assume that $\lambda_L^2 = 1$. Then employment in state $L$ comes solely from $c^1$, and since $\lambda_L^1 = 0$, it must be $A$. Now lower $\lambda_L^2$ but not down to zero. This leads to a violation of the IC–constraint $V(c^1, R_1) \geq V(c^2, R_1)$, but it can be restored back to equality by increasing $w^1$, and since we know that $\lambda_H^1 = \lambda_L^1 = 0$, and $w^2 = R_2$, $w^1$ will only have to be increased up to a level strictly below $R_2$. Then the $R_1$-workers will still sign $c^1$, and the $R_2$-workers will sign $c^2$. The rationing probability $\lambda_L^2$ can be set such that exactly $(l' - A)$ workers become employed on $c^2$ in

state $L$, where $l'$ is from A5. Thus employment in state $L$ increases from $A$ to $l'$. The extra empolyment in state $L$ on $c^2$ makes expected profit increase by at least $\psi_L [z_L T'(l') - R_2](l' - A)$. On the other hand the increase in $w^1$ makes the $A$ workers hired on $c^1$ (in both states) more expensive. However, the necessary increase in $w^1$ is less than $(R_2 - R_1)$. In total, expected profit willl have increased by at least $\psi_L [z_L T'(l') - R_2](l' - A) - A(R_2 - R_1)$. But this is positive from A5.

5. We show that $\lambda_H^2 = 0$. Assume that $\lambda_H^2 > 0$. Lower $\lambda_H^2$ by $\varepsilon/\psi_H$, and increase $\lambda_L^2$ by $\varepsilon/\psi_L$, $\varepsilon > 0$, but small (this can be done since $\lambda_L^2 < 1$). The full lapse of $V(c^2, R) = [\psi_H (1 - \lambda_H^2) + \psi_L (1 - \lambda_L^2)] U(R_2 - R)$ as a function of $R$ is unchanged. So, all IR- and IC-constraints are still fulfilled. The change in expected profit is greater than or equal to $\psi_H (z_H T'(1) - R_2) \dfrac{\varepsilon}{\psi_H} + \psi_L (z_L T'(A) - R_2) \left(-\dfrac{\varepsilon}{\psi_L}\right) = (z_H T'(1) - z_L T'(A))\varepsilon > 0$ by A4.

6. The equation (4) is just the IC-constraint for the $R_1$-workers, which we known from 1. must be fulfilled with equality, with the results obtained inserted. □

Equation (4) of Claim 6, gives a link between $w^1$ and $\lambda$, and we denote it by $\lambda(w^1)$. Clearly, $\lambda(R_2) = 0$, and for some lower $\overline{w}^1$, where $R_1 < \overline{w}^1 < R_2$, we have $\lambda(\overline{w}^1) = 1$. The function $\lambda(\cdot)$ is defined on $[\overline{w}^1, R_2]$ and strictly decreasing. Since we know that in a restricted optimum we must have $0 < \lambda^* < 1$, we also know that $\overline{w}^1 < w^{1*} < R_2$. The derivative $\lambda'(w^1)$ is obtained by implicit differentiation of (4),

$$\lambda'(w^1) = -\frac{1}{\psi_L} \frac{U'(w^1 - R_1)}{U(R_2 - R_1)}.$$

Using $\lambda(w^1)$, we can write the firm's expected profit in a restricted optimum as a function of $w^1$ alone (we insert $\lambda_H^1 = \lambda_L^1 = \lambda_H^2 = 0$, $w^2 = R_2$, and $\lambda_L^2 = \lambda(w^1)$ into $\overline{\pi}(c^1, c^2)$),

$$\begin{aligned} \tilde{\pi}(w^1) \equiv \psi_H & [z_H T(1) - w^1 A - R_2 (1 - A)] \\ & + \psi_L [z_L T(A + (1 - \lambda(w^1))(1 - A)) \\ & \qquad - w^1 A - R_2 (1 - \lambda(w^1))(1 - A)]. \end{aligned}$$

A restricted optimum can be found by maximizing $\tilde{\pi}(w^1)$ over $w^1$ fulfilling $\overline{w}^1 \le w^1 \le R_2$. From above we known the solution is interior, so $w^{1*}$ must fit in $\tilde{\pi}'(w^1) = 0$. Differentiating $\tilde{\pi}(w^1)$, and using $\lambda'(w^1)$ from above gives,

$$\begin{aligned} (5) \qquad & -\psi_H A + (1 - A) \frac{U'(w^1 - R_1)}{U(R_2 - R_1)} \\ & \quad \times [z_L T'(A + (1 - \lambda(w^1))(1 - A)) - R_2)] = 0. \end{aligned}$$

The left hand side of (5), $\tilde{\pi}'(w^1)$, is strictly decreasing in $w^1$. This means that the restricted optimum is unique. It is also clear from (5) that given $U(\cdot)$, $\psi_H$, and $\psi_L$, and thereby $\lambda(\cdot)$, it is possible, by choosing $z_L$ and $T(\cdot)$ appropriately, to ensure that the solution $w^{1*}$ to $\tilde{\pi}'(w^1) = 0$, comes arbitrarily close to $R_2$. Thus $\lambda^*$ comes arbitrarily close to zero, and employment, $A + (1 - \lambda^*)(1 - A)$, comes arbitrarily close to 1: Fix some small $\varepsilon > 0$. Consider the employment level $\underline{l} \equiv A + (1 - \lambda)(R_2 - \varepsilon))(1 - A)$. Now $z_L$ and $T(\cdot)$ can be chosen to make $z_L T'(\underline{l})$ as large as wanted. But this suffices for ensuring that $\tilde{\pi}'(R_2 - \varepsilon) > 0$, and thus $w^{1*} > R_2 - \varepsilon$. This choice of $z_L$ and $T(\cdot)$ can be made so that is does not contradict A1–A6. To the contrary; to have a very large marginal revenue $z_L T'(l)$ close to $l = 1$, pulls in the direction of making A1–A6 fulfilled. This proves Claim 7.

CLAIM 7: There is only one restricted optimum, $c^{1*} = (w^{1*}, 0, w^{1*}, 0)$, and $c^{2*} = (R_2, 0, R_2, \lambda^*)$, where $w^{1*}$ is the unique solution to (5), and $\lambda^* = \lambda(w^{1*})$. In this optimum $w^{1*}$ may be arbitrarily close to $R_2$, and $\lambda^*$ may be arbitrarily close to 0, for appropriate revenue technologies.

If the restricted optimum given by $(w^{1*}, \lambda^*)$ is close to $(R_2, 0)$, it will exhibit almost no fluctuations *in employment.* Also in that case there may be good reasons to create (unrestricted) pairs of contracts involving fluctuations *in wages* as we now show. We drop the restriction (3), and provide sufficient conditions for contract $c^2$ to exhibit wage fluctuations in and unrestricted optimal pair of contracts. Since $0 < A < 1$, the condition in (ii) of Theorem 2, e.g., reads that the Arrow-Pratt measure of absolute risk aversion $-U''/U'$, must be sufficiently much larger at $R_2 - R_1$ that at 0. This means that a worker with a given reservation wage becomes more risk averse as his income increases, which is unreasonable. However, it also means that at a given income workers with lower reservation wages are more risk averse than workers with higher reservation wages. This is very plausible. As can be seen from the proof of Theorem 2, and explained intuitively in the concluding section, it is the *second* feature which is crucial for our result. Both features are implied by (ii), since we work with the special utility function $U(w - R)$. If the utility function had been specified as $U(w, R)$, rather than as $U(w - R)$, one could have had that risk aversion for a given worker was decreasing in both income and reservation wage at the same time.

THEOREM 2: (i) *If*

$$-\frac{U''(R_2 - R_1)}{U'(R_2 - R_1)} A \frac{U'(R_2 - R_1)}{U'(0)} > -\frac{U''(0)}{U'(0)},$$

*then any optimal pair of contracts* $(c^1, c^2)$ *involves wage fluctuations on* $c^2$*, that is,* $w_H^2 \neq w_L^2$.

(ii) *If,*

$$-A \frac{U''(R_2 - R_1)}{U'(R_2 - R_1)} > -\frac{U''(0)}{U'(0)}.$$

*then there exist revenue technologies* $(z_L, z_H, T(\cdot))$*, namely those bringing the restricted optimum close to* $(R_2, 0)$*, such that any optimal pair of contracts exhibit wage fluctuations on* $c^2$.

*Proof:* (i) Start from the restricted optimum $c^{1*} = (w^{1*},\, 0,\, w^{1*},\, 0)$, $c^{2*} = (R_2,\, 0,\, R_2,\, \lambda^*)$, and allow then more general contract pairs of form $c^1 = (w^1,\, 0,\, w^1,\, 0)$, $c^2 = (w_H^2,\, 0,\, w_L^2,\, \lambda^*)$. We show that increasing $w_H^2$ and decreasing $w_L^2$ increases the expected profit compared with the restricted optimum. This is sufficient to prove that there will be wage fluctuations in the unrestricted optimum (since the restricted optimum gives the best possible without wage fluctuations).

Close to $(c^{1*},\, c^{2*})$ we still have $V\,(c^2,\, R_2) = 0$, and $V\,(c^1,\, R_1) = V\,(c^2,\, R_1)$. These restrictions now take the form,

$$\psi_H\, U\,(w_H^2 - R_2) + \psi_L\,(1-\lambda^*)\, U\,(w_L^2 - R_2) = 0,$$

which can be viewed as giving $w_L^2$ as a function of $w_H^2$, $w_L^2\,(w_H^2)$, and

$$U\,(w^1 - R_1) = \psi_H\, U\,(w_H^2 - R_1) + \psi_L\,(1-\lambda^*)\, U\,(w_L^2 - R_1),$$

which can be viewed as giving $w^1$ as a function of $(w_H^2,\, w_L^2)$, $w^1\,(w_H^2,\, w_L^2)$. By differentiating these two expressions implicitly and evaluating the obtained derivatives at the restricted optimum where $w_H^2 = w_L^2 = R_2$, and $w^1 = w^{1*}$, we get

$$\frac{dw_L^2}{dw_H^2} = -\frac{\psi_H}{\psi_L}\,\frac{1}{1-\lambda^*},$$

$$\frac{d^2 w_L^2}{dw_H^{2_2}} = -\frac{\psi_H}{\psi_L}\,\frac{1}{1-\lambda^*}\,\frac{U''\,(0)}{U'\,(0)}\left(1 + \frac{\psi_H}{\psi_L}\,\frac{1}{1-\lambda^*}\right),$$

$$\frac{\partial w^1}{\partial w_H^2} = \psi_H\,\frac{U'\,(R_2 - R_1)}{U'\,(w^{1_*} - R_2)},$$

$$\frac{\partial^2 w^1}{\partial w_H^{2_2}} = \psi_H\,\frac{U'\,(R_2 - R_1)}{U'\,(w^{1_*} - R_1)} \times \left[\frac{U''\,(R_2 - R_1)}{U'\,(R_2 - R_1)} - \psi_H\,\frac{U''\,(w^{1_*} - R_1)}{U'\,(w^{1_*} - R_1)}\,\frac{U'\,(R_2 - R_1)}{U'\,(w^{1_*} - R_1)}\right],$$

$$\frac{\partial w^1}{\partial w_L^2} = \psi_L\,(1-\lambda^*)\,\frac{U'\,(R_2 - R_1)}{U'\,(w^{1_*} - R_1)},$$

$$\frac{\partial^2 w^1}{\partial w_L^{2_2}} = \psi_L\,(1-\lambda^*)\,\frac{U'\,(R_2 - R_1)}{U'\,(w^{1_*} - R_1)} \times \left[\frac{U''\,(R_2 - R_1)}{U'\,(R_2 - R_1)} - \psi_L\,(1-\lambda^*)\,\frac{U''\,(w^{1_*} - R_1)}{U'\,(w^{1_*} - R_1)}\,\frac{U'\,(R_2 - R_1)}{U'\,(w^{1_*} - R_1)}\right],$$

$$\frac{\partial^2 w^1}{\partial w_H^2 \partial w_L^2} = -\psi_H \psi_L\,(1-\lambda^*)\,\frac{U'\,(R_2 - R_1)^2}{U'\,(w^{1_*} - R_1)^3}\, U''\,(w^{1_*} - R_1).$$

The expected profit from a contract pair $(c^1, c^2)$ of the more general form, given the two links is

$$\begin{aligned}\overline{\pi}(c^1, c^2) = \psi_H\,&[z_H\,T(1) - w^1 A - w_H^2(1-A)]\\ &+\psi_L\,[z_L T(A + (1-\lambda^*)(1-A))\\ &\qquad - w^1 A - w_L^2(1-\lambda^*)(1-A)].\end{aligned}$$

Using the function $w_L^2(w_H^2)$ from the first link, and the function $w^1(w_H^2, w_L^2)$ – hence $w^1(w_H^2, w_L^2(w_H^2))$ – from the second (and first), profit can be viewed as a function of $w_H^2$ alone, that is, $\hat{\pi}(w_H^2)$. Differentiating this yields

$$\frac{d\hat{\pi}}{dw_H^2} = -A\left[\frac{\partial w^1}{\partial w_H^2} + \frac{\partial w^1}{\partial w_L^2}\frac{dw_L^2}{dw_H^2}\right] - (1-A)\left[\psi_H + \psi_L(1-\lambda^*)\frac{dw_L^2}{dw_H^2}\right].$$

Evaluating this derivative at the restricted optimum, that is, inserting the first order derivatives above, gives $d\hat{\pi}/dw_H^2 = 0$. It is therefore a sufficient condition for profit to be increased by a small increase in $w_H^2$ that the second order derivative of $\hat{\pi}$ is strictly positive. Differentiating the above expression for $d\hat{\pi}/dw_H^2$ once more and then inserting the first and second order derivative above give (after tedious computations),

$$\begin{aligned}\frac{d^2\hat{\pi}}{dw_H^{2_2}} &= \psi_H\left(1 + \frac{\psi_H}{\psi_L}\frac{1}{1-\lambda^*}\right)\\ &\times\left[-A\frac{U''(R_2 - R_1)}{U'(w^{1*} - R_1)} + \frac{U''(0)}{U'(0)}\left(A\frac{U'(R_2 - R_1)}{U'(w^{1*} - R_1)} + 1 - A\right)\right].\end{aligned}$$

This has the same sign as the square bracket which, since $R_1 < w^{1*} < R_2$, is certainly larger than

$$\begin{aligned}&-A\frac{U''(R_2 - R_1)}{U'(R_1 - R_1)} + \frac{U''(0)}{U'(0)}\left(A\frac{U'(R_2 - R_1)}{U'(R_2 - R_1)} + 1 - A\right)\\ &= -A\frac{U''(R_2 - R_1)}{U'(R_1 - R_1)} + \frac{U''(0)}{U'(0)}.\end{aligned}$$

The condition of (i) comes from requiring this expression larger than zero.

(ii) Return now to the second order derivative $d^2\hat{\pi}/dw_H^{2_2}$, and evaluate it at $w_1 = R_2$, $\lambda^* = 0$, $w_H^2 = w_L^2 = R_2$. (This is the point to which the restricted optimum can be brought arbitrarily close). This is just obtained by inserting into the above expression for $d^2\hat{\pi}/dw_H^{2_2}$, $w^{1*} = R_2$, and $\lambda^* = 0$,

$$\frac{d^2\hat{\pi}}{dw_H^{2_2}} = \frac{\psi_H}{\psi_L}\left[-A\frac{U''(R_2 - R_1)}{U'(R_2 - R_1)} + \frac{U''(0)}{U'(0)}\right].$$

This is strictly positive exactly under the condition of (ii). This time we did not evaluate at the restricted optimum, $w^1 = w^{1*}$, but rather at $w^1 = R_2$. However, if the second derivative is strictly positive at $w^1 = R_2$, then it is also strictly positive for smaller, but sufficiently close, $w^1$. That is, for the restricted optimum sufficiently close to $R_2$, the condition of (ii) ensures that an optimal contract pair will exhibit wage fluctuations. □

# 5 Concluding Remarks

The utility function we have used is $U(y)$, where $y$ is the wage income's excess over reservation wage for the worker in question. Both of the conditions of Theorem 2, ensuring that pairs of optimal contracts will exhibit wage fluctuations over the cycle, take the form: The Arrow-Pratt measure of absolute risk aversion is sufficiently much larger at $y = R_2 - R_1$, than at $y = 0$.

For von NEUMANN-MORGENSTERN utility functions defined on *money* one would say that the mesure of absolute risk aversion is *decreasing* in money income or wealth. One could therefore ask if the conditions of Theorem 2 are simply in the opposite direction of what is usually assumed and thus very implausible? This is not the case. In our model utility is *not* defined on money income, which would here be $w$, but on the income's excess over an alternative income opportunity, $w - R$. The right reading of the condition in (ii) of Theorem 2, for instance, is the following: The measure of absolute risk aversion at a money income of $R_2$ for workers with reservation wage $R_1$ – the left hand side – is sufficiently much larger than this measure, also at a money income of $R_2$, for workers with reservation wage $R_2$ – the right hand side. To be precise, $A$ times the first is larger than the second. Basically, our conditions say that at a given money income workers with low reservation wages are sufficiently much more risk averse than workers with high reservation wages. This is plausible since we may think of workers with bad alternative income opportunities as being relatively "weak" and therefore risk averse.

Consider a standard example of a utility function with increasing absolute risk aversion, $U(y) = b^a - (b-y)^a$, where $a$ and $b$ are parameters, and $a > 1$, $b > 0$. The ARROW-PRATT measure of absolute risk aversion is $-\frac{U''(y)}{U'(y)} = \frac{a-1}{b-y}$. The condition of (ii) is fulfilled if and only if $R_2 - R_1 > b(1-A)$.

The intuition behind our results can be explained as follows. When workers are different it is natural to imagine that the firm offers two different contracts instead of just one. The potential gain from this comes from a wage discrimination effect. The firm cannot observe the individual worker's type, so wage discrimination requires that workers perform self–selection. By making the contract designed to attract the strong workers – those with high reservation wages – risky, the firm may manage to make the weaker workers prefer another contract with lower expected wage. This may therefore increase the firm's expected profit. The Claim 4 of Section 3 demonstrates that such wage discrimination is optimal. An interesting further question is: Could it be that optimal wage discrimination necessarily involves *wage* fluctuations?

If so it should, according to the above intuition, be on the contract designed for the strong workers. Assume for a moment that this does *not* exhibit wage fluctuations. Then it suffices, of course, to set its fixed wage at the reservation wage of the strong workers to attract these. Further, the fixed wage of the contract designed to attract the weak workers can be assumed to be lower. Consider the operation of splitting the wages in the high and the low state, respectively, on the contract for the strong workers, but in a way so that it can still attract these. Since they are risk averse this requires that its average wage increases. *If* now this contract, by having its wages splitted as described, becomes worse for the weak workers, then the fixed wage on the weak workers' contract can be decreased and still the weak workers will go for it. What points in the direction of making this possible is that the weak workers are more risk averse than the strong workers at the latters' reservation wage. (In fact, it is possible exactly if the weak workers have a higher measure of absolute risk aversion than the strong workers at a wage equal to the strong worker's reservation wage, as may easily be proved). The possibility of decreasing this wage is not enough to ensure that expected profit increases. The original splitting of wages itself makes the expected wage bill on the strong workers' contract larger. Intuitively, however, if the weak workers are sufficiently much more risk averse than the strong workers (at the latters' reservation wage) then the full operation is profitable. The conditions of Theorem 2 spell out this basic intuition.

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