Entry wages signalling the credibility of future wages: a reinterpretation of the turnover-efficiency-wage model

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Abstract. For both empirical and theoretical reasons, the mechanism by which existing efficiency-wage models link job rationing with turnover costs is unsatisfactory. This paper extends the standard turnover-efficiency-wage model by formally examining the determination of wages as the outcome of a self-enforcing contract. The problem is analysed as a game of asymmetric information in which the entry level wage plays a signalling role about the credibility of the future wage payments. Suggestive evidence in favour of the model is provided by an examination of the restrictions imposed on wage profiles.

Niveaux de salaires à l'entrée comme signaux de la crédibilité des salaires futurs: une réinterprétation du modèle des salaires d'efficience et des coûts de roulement. Pour des raisons empiriques et théoriques, le mécanisme par lequel les modèles de salaires d'efficience lient le rationnement des emplois et les coûts de roulement est insatisfaisant. Ce mémoire suggère une extension du modèle standard en examinant la détermination des salaires comme le résultat d'un contrat qui s'auto-exécute. Le problème est analysé comme un jeu avec information asymétrique dans lequel le niveau de salaire à l'entrée joue un rôle de signal de la crédibilité des futurs paiements de salaires. L'examen des restrictions imposées aux profils de salaires fournit support au modèle.

I. INTRODUCTION

There is a long tradition in economics that suggests that job rationing and unemployment may result from wages being set to reduce employee turnover instead of adjusting to equate supply and demand. However, the standard explanation for this phenomena, as presented by Stiglitz (1974, 1985) and Salop (1979), has been harshly criticized on the grounds that it unjustifiably limits contracting possibili-

The author wishes to thank Ben Bernanke, David Card, John DiNardo, Bob Gibbons, Kevin Lang, Thomas Lemieux, Michel Poitevin, David Romer, Andy Weiss, and Joseph Stiglitz for helpful comments. The author also wishes to thank Brian McCall for access to a well-organized data set.

Canadian Journal of Economics Revue canadienne d'Economique, XXVII, No. 4
November novembre 1994. Printed in Canada Imprimé au Canada

0008-4085 / 94 / 884–902 $1.50

ties. The payment of efficiency wages arises in the standard turnover model only because employers are restricted to pay the same wage to a new hire as to a trained worker. Besides being an unwarranted assumption, this restriction is also empirically questionable, since many studies find that wages rise rapidly in the early stages of employment relationships.[1] Therefore, if turnover considerations are a cause of job rationing, a complete and empirically relevant explanation for this phenomenon appears to be missing.

In the light of the difficulties of the standard turnover-efficiency-wage model, the goal of this paper is to re-examine the turnover-efficiency-wage model within the context of a game of asymmetric information wherein firms offer self-enforcing contracts in which entry-level wages differ from post-entry wages. The separating equilibrium of the game is shown to be characterized by the entry-level wage signalling the credibility of the proposed future wage payments. One potential criticism of the approach adopted in the paper is that reputation could overcome both the commitment problem and the asymmetric information problem. Although this is surely possible, the empirical literature on job reallocation and gross job flows (see Davis and Haltiwanger 1990) indicates that worker mobility is extremely high and therefore suggests that the information flow needed to allow reputation mechanisms to function properly may not be present in all job openings. Moreover, Carmichael (1989) has highlighted many circumstances in which requiring contracts to be self-enforcing provides helpful insights into the functioning of the labour market.[2] Therefore, it remains an empirical question whether limiting information flows and forcing contracts to be self-enforcing provide an appropriate framework for analysing wage determination.[3]

The remaining sections of the paper are structured as follows. In section II, which is the central section of the paper, the standard turnover-efficiency-wage model is extended to allow entry-level wages to differ from post-entry wages. Empirical restrictions implied by the model are deduced in section III and suggestive evidence in favour of the approach is presented in section IV. Section V offers concluding comments.

II. THE THEORY

The loss in firm-specific human capital is often regarded as an important factor in understanding why employers dislike employee turnover. As a consequence, employers are believed to set wages in a manner that discourages experienced

1 There is a debate on whether prolonged tenure profiles are prevalent, for example, see Abraham and Farber (1987). However, this debate does not generally place in doubt the existence of a tenure profile in the first year (or two) of employment relations; for more details see Brown (1989) and Altonji and Shakotko (1987) on this issue.

2 For examples, see MacLeod and Malcomson (1988, 1989).

3 Although firms can often write employment contracts that are enforceable by courts, in practice they are not used extensively. One reason may be that the litigation costs are rather high, thereby rendering unattractive the use of courts as an enforcement device. Another reason may be that court-enforced contracts lack flexibility and create severe moral hazard problems.

workers from quitting. In order to recall why such turnover considerations are said to lead to the payment of efficiency wages, consider the profit maximizing choice of wages for a job that features the accumulation of firm-specific human capital. To keep things simple, consider a situation where a new hire produces Φ_1 in the first period of employment and produces $\Phi_1 + \Theta$ in all subsequent periods; that is, the worker accumulates Θ of firm-specific human capital in the learning stage of the employment relation. The employer's preferred wage policy for such a job generally depends on the available contracting possibilities. The standard turnover-efficiency-wage model assumes that the employer can set only a single wage throughout a job and that a worker cannot be restricted from quitting. In this case, the employer's optimal wage payment w is a function of the worker's outside job opportunities and of the value to the firm of a vacancy V. Assuming that a worker's outside opportunities can be represented by employment offers drawn independently each period from the cumulative density function $Q(\cdot)$, where the value of an offer is translated into a fixed wage equivalent, the wage for this job that maximizes the employer's discounted profits is defined in equation (1). Note that the probability that a worker stays with the job in any period can be represented by $Q(w)$, since for all outside wage-equivalent offers above w the worker quits the job to pursue alternative employment.

$$\arg\max_{w} \Phi_1 - w + \sum_{n=1}^{\infty}\{\delta^n Q(w)^n\{\Phi_1 + \Theta - w\} + \delta^n Q(w)^{n-1}(1 - Q(w))V\}. \tag{1}$$

Since the solution to (1) can imply a wage that is higher than an unemployed worker considers his reservation value, this situation is said to explain the payment of efficiency wages. As discussed in the introduction, however, the assumption that an employer is restricted to pay the same wage in all periods is theoretically and empirically unappealing. On the one hand, this restriction is at odds with the empirical literature on wage profiles. For example, Altonji and Shakotko (1987) and Brown (1989) find significant increases in wages over the time span for which workers say they are learning a job. On the other hand, an employer in this situation would always want to lower the entry-level wages, since doing so would reduce wage costs without having a negative impact on turnover. Therefore, it seems important to examine whether this efficiency wage result can still arise when entry-level wages are not restricted to being equal to post-learning wages.

One reason that is often invoked for explaining why workers may be reluctant to accept jobs with very low entry-level wages is the perverse incentives that such low wages can create on employers. For example, when the difference between entry-level wages and post-learning wages is important, an employer generally has an incentive either to fire a worker or to renegotiate the wage once the low-wage period is completed. This line of reasoning suggest that the credibility of promised future wages is an important concern in many segments of the labour market. Consequently, one way to improve on the standard turnover model is to examine the implications of allowing the employer to set different wages across time while also adopting the assumption that any agreed-upon wage contract must be self-enforcing in order to be credible.

1. A modified contract offer game

In this section the determination of wages is analysed in the form of a game of asymmetric information between an employer and a worker. The set-up of the game maintains the same technology and the same description of a worker's outside opportunities as previously stated. The following five stages represent the timing of play in a game where the employer offers an implicit contract covering both the entry-level wage and the post-learning wage but cannot commit not to renege on the contract once the learning period is completed.

Stage 1: The employer offers a wage contract to the worker. The wage contract specifies two wages: an entry-level wage, w_1, and a post-entry wage w_2.

Stage 2: The worker either accepts or rejects the offer. If he accepts the offer, employment begins, the worker receives the payment of w_1 and produces Φ_1. If he rejects the offer, the game ends and both the firm and the worker receive their reservation values denoted V and U, respectively.

Stage 3: During employment, the worker receives an outside job offer which is unobserved by the employer and for which the wage-equivalent is drawn from $Q(w)$. The worker either rejects the offer and pursues his present job into the post-learning phase, or he accepts the offer and quits his current job at the end of the period. If the worker quits the job, he receives the present discounted value associated with pursuing the alternative job.

Stage 4: If the worker pursues his current job into the post-learning phase, the employer can either abide by the initial contract or he can renege on the contract and make an alternative wage offer. Again, the worker has the option of quitting the job and receiving his resevation utility (thereby ending the game), or he can decide to continue working for the employer at the currently stated wage.

Stage 5: In all remaining periods, the worker continues to receive outside wage-equivalent offers drawn from $Q(w)$ and can decide at any time to quit his current job in favour of the alternative offer; otherwise he continues employment at the wage determined in stage 4 and produces $\Phi_1 + \Theta$.

Before we characterize the equilibrium of this game, it is necessary to specify the information structure. It is assumed that a worker knows only his initial productivity (Φ_1) when hired, but he does not know how much firm-specific human capital he will acquire during the learning period, that is, Θ is known only by the employer.[4] This assumption seems reasonable when the value of firm-specific capital is hard to measure and therefore requires a subjective evaluation by the

4 Frank (1987) and Giammarino and Nosal (1990) also consider employment situations where there is asymmetric information on the part of the employer. These papers focus on the substantially different issue of how asymmetric information can explain the limited variation in wages over the business cycle.

emplóyer, which necessarily is private information. The assumption furthermore requires that information flows across workers about Θ be sufficiently limited or uninformative, which may also to be reasonable if there is substantial turmoil in the labour market in terms of both worker turnover and technological change. Consequently, the analysis will concentrate on the version of the game in which, at stage 0, nature chooses $\Theta \in [\Theta_L, \Theta_H]$ and reveals it only to the employer. It is assumed throughout that jobs differ only with respect to Θ, and therefore a job in which the worker accumulates Θ of firm-specific capital is referred to as a type-Θ job. Since the game is one of imperfect information, the equilibrium concept used to characterize behaviour will be that of Perfect Bayesian Equilibrium.[5]

There are two other details of the game that require further explanation before the equilibrium analysis can be carried out. First, the game is assumed to end whenever the worker refuses employment or quits the job. In either of these cases, the employer receives an exogenous pay-off, denoted V, which is meant to represent the future value of the vacancy. Since the value of a vacancy may depend on the type of job, it is reasonable to allow V to depend on Θ and denote this pay-off more generally by $V(\Theta)$. The only restrictions placed on $V(\cdot)$ are that it be increasing in Θ and that it have no greater than unit elasticity with respect to Θ. Although these properties are assumed to hold from the outset, it is easy to verify that they are actually consistent with the equilibrium behaviour that will be derived. Secondly, whenever the worker refuses employment and stays unemployed, it is assumed that he receives a pay-off of U. This pay-off represents both his utility of currently remaining unemployed, denoted w_R, and his expected future utility associated with optimally selecting jobs drawn from $Q(w)$. In order to ensure that employment always involves gains from trade, the current utility of remaining unemployed is assumed to be less than Φ_1. Note that the worker may nevertheless accept an entry wage lower than Φ_1 in expectation of higher wages in the future. Allowing for Φ_1 to be less than the current utility of remaining unemployed does not change any of the results, as discussed in footnote 8, but it simplifies the analysis.

Although the game is rather involved, it considerably simplifies matters to recognize that the structure of this game is similar to most signalling games. All signalling games have the following three elements: (1) an initial move by the informed players which acts as a signal, (2) a response by the uninformed player which matters to the informed player, and (3) private information which is of interest to the uninformed player. In the present game these elements correspond, respectively, to: the implicit contract offer (stage 1); both the worker's acceptance decision and his decision as to what outside offers to pursue (stages 2 and 3); and the information regarding whether the employer will abide by the implicit contract (stage 4). It is only the last stage that is separate from the signalling aspect of the game. In stage 5, the worker knows the post-learning wage and therefore no longer needs to infer anything from the employer's behaviour.

As is common in most signalling situations, there are potentially many equilibria for this game. For example, the game can actually support play in which the initial

5 See Fudenberg and Tirole (1990) for a precise definition of a Perfect Bayesian Equilibrium.

contract offer is always respected in equilibrium as well as play in which it is not. The strategy adopted in the paper is first to examine the characteristics of equilibria in which the initial contract is respected in equilibrium (i.e., equilibria in which the contract is self-enforcing) and then to discuss why this type of equilibrium seems most relevant.

2. Equilibrium analysis of signalling contracts

In all equilibria of the game in which the implicit contract is respected, the strategy of the employer can be represented by a pair of functions $\{w_1(\cdot), w_2(\cdot)\}$, where the pair of functions represents both the initial contract offer and the actual wage paid in the post-learning stage as a function of Θ. For example, $\{w_1(\Theta), w_2(\Theta)\}$ specifies the initial contract offer when the job is of type Θ, while $w_2(\Theta)$ also specifies the actual post-learning wage paid to a trained worker. In order to find such pair of functions, it is easiest to begin at the end and determine the $w_2(\cdot)$ function. In particular, sequential rationality requires that the post-learning wage maximize the employer's continuation profits, denoted $\Pi^c(\Theta)$, evaluated for the subgame starting from stage 4; that is, $w_2(\Theta)$ must solve (2) for all Θ.

$$\Pi^c(\Theta) = \max_{w} \sum_{n=0}^{\infty} \delta^n Q(w)^n\{\Phi_1 + \Theta - w\} + \sum_{n=1}^{\infty} \delta^n Q(w)^{n-1}(1 - Q(w))V(\Theta). \quad (2)$$

$$\text{s.t. } w \geqq w_R$$

The choice of w_2 is made by trading-off the direct wage cost with the cost associated with losing an experienced worker and therefore there is no signalling aspect involved. The signalling aspect of the game arises only at stage 1, at which time the worker must try to infer whether proposed future wage payments are credible based on the signal sent by the entry-level wage. The first-order condition associated with an interior solution to (2) is given by (3):

$$(1 - \delta Q(w_2)) = \delta Q'(w_2)\{\Phi_1 + \Theta - w_2 - (1 - \delta)V(\Theta)\}. \quad (3)$$

Equation (3) implicitly defines the optimal post-learning wage $w_2^*(\Theta)$. From (3), it is easy to verify that $w_2^*(\Theta)$ is strictly increasing in Θ. In other words, jobs in which learning is more important are associated with higher post-learning wages. Nevertheless, since we have yet to determine the $w_1(\cdot)$ function, (3) does not imply that a worker would prefer a higher Θ job, since entry-level wages may be set low enough to compensate for high post-learning wages. In particular, if the job type was known by the worker (symmetric information case), the employer could always set the entry-level wage such that the worker is simply indifferent between accepting or refusing the contract (see Hall and Lazear 1984). This would lead an employer with a high Θ job to pay a low-entry wage and a high post-learning wage relative to an employer with a low Θ job.

One implication of the monotonicity of $w_2^*(\Theta)$, combined with the requirement that contracts be self-enforcing, is that a worker must be able to infer the type of job from the initial contract offer. The requirement that contracts be self-enforcing is in fact imposing that the initial contract signals the type of job. Therefore, it must be the case that in a self-enforcing equilibrium an employer does not want to fool the worker by pretending the job is of a different type. The set of incentive compatibility constraints related to this condition is represented under (4), where $\{w_1^*(\cdot), w_2^*(\cdot)\}$ represents the set of conjectured self-enforcing contracts. The left-hand side of (4) represents the pay-off to the employer of type $\tilde{\Theta}$ of following the equilibrium strategy by offering $\{w_1^*(\tilde{\Theta}), w_2^*(\tilde{\Theta})\}$. The right-hand side represents the pay-off to the same employer of initially deviating by offering a contract $\{w_1^*(\hat{\Theta}), w_2^*(\hat{\Theta})\}$ and then optimally reneging on the contract in the post-learning stage by offering $w_2(\tilde{\Theta})$.

$$\forall\, \tilde{\Theta} \text{ and } \hat{\Theta},\ \{\Phi_1 - w_1^*(\tilde{\Theta})\} + \delta Q(w_2^*(\tilde{\Theta}))\Pi^c(\tilde{\Theta}) + \delta(1 - Q(w_2^*(\tilde{\Theta})))V(\tilde{\Theta})$$
$$\geqq \{\Phi_1 - w_1^*(\hat{\Theta})\} + \delta Q(w_2^*(\hat{\Theta}))\Pi^c(\tilde{\Theta}) + \delta(1 - Q(w_2^*(\hat{\Theta})))V(\tilde{\Theta}). \qquad (4)$$

The restrictions on $w_1^*(\Theta)$ implied by (4) can best be seen by regrouping terms as in (5). The right-hand side of (5) is positive if $\hat{\Theta}$ is greater than $\tilde{\Theta}$, since both $Q(\cdot)$ and $w_2(\cdot)$ are increasing functions. This implies that the left-hand side of (5) must also be positive whenever $\hat{\Theta}$ is greater than $\tilde{\Theta}$. Therefore, in order to satisfy the incentive compatibility constraints, $w_1^*(\Theta)$ must increase with Θ.

$$w_1^*(\hat{\Theta}) - w_1^*(\tilde{\Theta}) \geqq \delta\{Q(w_2^*(\hat{\Theta})) - Q(w_2^*(\tilde{\Theta}))\}\{\Pi^c(\tilde{\Theta}) - V(\tilde{\Theta})\}. \qquad (5)$$

Without having yet determined the form of $w_1^*(\cdot)$, inequality (5) by itself implies the following important result.

PROPOSITION 0. *In any equilibrium where the contract is always respected, a worker will strictly prefer to be employed in a higher Θ job.*

The higher Θ job is preferred by a worker, since an employer with the higher Θ job offers and abides by a contract that pays both a higher entry-level wage and a higher post-learning wage. This result indicates that turnover considerations can lead to the payment of efficiency wages even when entry-level wages are allowed to be set differently from post-learning wages. The intuition for why entry-level wages must increase with Θ is that a higher entry-level wage acts as signal of the credibility of a high future wage payment. If the entry-level wage did not increase with Θ, the employer would always want to fool the worker into believing that the post-learning wages will be very high so that the worker stays with the employer. It is the signalling cost that stops him from doing so. Nevertheless, an employer with a high Θ is willing to pay a high entry-level wage in order to signal the value of pursuing the relationship into the post-learning stage. Since the model allows entry-level wages to be set arbitrarily low, the entry-level wage can be interpreted as playing the role of an entrance fee. Therefore, in response to Carmichael's (1984) important criticism of efficiency-wage models, employers in this model would not use an entrance fee to eliminate efficiency wages, since it would signal that the implicit contract that covers future wages is not credible.

The employer's incentive to signal results from the possibility that the worker quit during the learning stage of the employment relation before he observes his post-training wage. Since this assumption is central to the model, it is deserves comment.[6] It may appear that this assumption implies the empirically questionable hypothesis that workers generally quit jobs without knowing how much they will be paid in the future. However, this is not the case: in the separating equilibrium of this model, a worker always knows the future wage and therefore makes his quit decision well informed. It is only out-of-equilibrium that he is misinformed. This means that the timing assumption is not at odds with the observation that workers are rather well informed at the time of quitting.

Although inequality (5) implies that high Θ jobs will always pay higher wages than lower Θ jobs, it cannot be directly inferred that this signalling approach offers a reasonable explanation to the turnover-efficiency-wage model. For example, there is nothing in (5) that indicates that post-learning wages are actually greater than entry-level wages, which is a minimal requirement for the model to be considered reasonable. Consequently, it is necessary to go beyond (5) and determine the precise form of $w_1^*(\cdot)$.

In order to derive $w_1^*(\cdot)$, let us restate the incentive compatibility constraints in terms of the first-order conditions associated with the following revelation problem. In particular, the revelation problem given by equation (6) states that if an employer of type $\tilde{\Theta}$ is asked to state the type of his job in stage 1, in a separating equilibrium it must be that truthfully revealing his type solves the maximization problem.[7]

$$\tilde{\Theta} = \arg\max_{\hat{\Theta}} \{\Phi_1 - w_1^*(\hat{\Theta})\} + \delta Q(w_2^*(\hat{\Theta}))\Pi^c(\tilde{\Theta}) + \delta(1 - Q(w_2^*(\hat{\Theta})))V(\tilde{\Theta}). \tag{6}$$

The first-order condition associated with (6) is represented in (7):

$$-\frac{dw_1^*(\hat{\Theta})}{d\hat{\Theta}} + \delta Q'(w_2^*(\hat{\Theta}))\{\Pi^c(\tilde{\Theta}) - V(\tilde{\Theta})\}\frac{dw_2^*(\hat{\Theta})}{d\hat{\Theta}} = 0. \tag{7}$$

Rewriting (7) and imposing truth telling for all Θ leads to (8):

$$\frac{dw_1^*(\Theta)}{d\Theta} = \delta Q'(w_2^*(\Theta))\{\Pi^c(\Theta) - V(\Theta)\}\frac{dw_2^*(\Theta)}{d\Theta}. \tag{8}$$

Equation (8) can be further simplified by using equation (3) and noting that

$$\{\Pi^c(\Theta) - V(\Theta)\} = \frac{(\Phi_1 + \tilde{\Theta} - w_2^*(\tilde{\Theta}) - (1-\delta)V(\tilde{\Theta}))}{(1 - \delta Q(w_2^*(\tilde{\Theta}))}.$$

6 Allowing the employer to respond to a worker's decision to accept another job by offering a counter proposal could obviously change the results of the model. However, the relevance of this possibility depends on both the credibility of the counter proposal and on the verifiability of outside offers, including its non-pecuniary aspects.

7 This method of characterizing the $w_1^*(\cdot)$ is very similar to that used in Spence (1974) and Riley (1979).

Replacing (3) into (8) leads to equation (9):

$$\frac{dw_1^*(\Theta)}{d\Theta} = \frac{dw_1^*(\Theta)}{d\Theta}. \tag{9}$$

The integration of both side of (9) from Θ_L to $\tilde{\Theta}$ results in equation (10) (recall that Θ_L is lowest type of job):

$$w_1^*(\tilde{\Theta}) + [w_2^*(\Theta_L) - w_1^*(\Theta_L)] = w_2^*(\tilde{\Theta}). \tag{10}$$

The interpretation of equation (10) is stated in the following proposition.

PROPOSITION 1. *For a contract offer to be credible in equilibrium it must specify a post-learning wage that is linearly related to the entry level wage in a ratio of one-to-one. Moreover, the intercept of this linear relation is given by the wage profile for the job of type Θ_L.*

The characterization of the signalling contract given by equation (10) indicates that jobs with different levels of on-the-job learning do not differentiate themselves by expected wage increases; they differentiate themselves only by the level of wages. In particular, to determine whether a proposed contract is credible, a worker needs only to examine whether the promised future payments are equal to the entry-level wage plus the average wage profile within his market.

Equations (3) and (10) almost completely characterize the conditions that must be satisfied for a contract to be self-enforcing. The only element missing is the determination of the wage profile on the job of type Θ_L, that is, $[w_2^*(\Theta_L) - w_1^*(\Theta_L)]$. This last element can be found by exploiting the Bayesian updating rule. The concept of Perfect Bayesian Equilibrium (PBE) requires that all beliefs be restricted to the support of admissible types. Therefore, the most pessimistic inference a worker can make regarding a type of job (and consequently the post-learning wage) is that it be of type Θ_L. This implies that an employer with a job of type Θ_L cannot receive an equilibrium pay-off that is worse than that associated with the worker's believing with certainty that the job is of type Θ_L (which implies that he will pay $w_2^*(\Theta_L)$ in the post-learning phase). Moreover, since the equilibrium is separating, the employer with this type of job can receive no more than that associated with the worker's believing it is a type Θ_L job. Consequently, the employer with a type Θ_L job will offer exactly the same contract as if the worker knew with certainty the identity of the job. This restriction on the equilibrium strategy of the Θ_L type, which is the type that no other type wants to mimic, is a general property of separating equilibria.[8]

8 In the case where Φ_1 is smaller than U_R, Θ_L in equation (10) would not correspond to the absolute lowest Θ but instead corresponds to the lowest Θ within the support of types that would find it profitable to offer employment under symmetric information. For further detail on this case see Beaudry (1989).

The previous discussion indicates that $[w_2^*(\Theta_L) - w_1^*(\Theta_L)]$ can be determined by examining the employer's optimal strategy in a symmetric information version of the game where $\Theta = \Theta_L$. When the worker knows that $\Theta = \Theta_L$, there is no signalling role for the entry-level wage, and therefore it is optimal for the employer to set the entry-level wage as low as possible. In particular, the employer should set $w_1^*(\Theta_L)$ such that the worker is just indifferent about accepting or rejecting the contract offer of $\{w_1^*(\Theta_L), w_2^*(\Theta_L)\}$. The worker will be ready to accept a contract with $w_1^*(\Theta_L) < w_2^*(\Theta_L)$ whenever $Q(w_2^*(\Theta_L)) < 1$; that is, whenever the probability of quitting the job is less than one. Under this last condition, which was implicitly assumed by the use of (3), the wage profile on a job of type Θ_L is positive. This last condition is stated under (11):

$$[w_2^*(\Theta_L) - w_1^*(\Theta_L)] > 0 \tag{11}$$

Note that since an employer with a job of type Θ_L strictly offers the lowest wage contract, and since a worker is merely indifferent between accepting or rejecting this contract, all jobs with Θ strictly greater that Θ_L can be interpreted as paying efficiency-wages. The relations (10) and (11) imply the following characteristics of signalling contracts.

PROPOSITION 2. *Signalling contracts have the property that entry-level wages are always lower than post-learning wages.*

Up to now, the analysis has derived only necessary conditions that must be satisfied for a contract to be self-enforcing. To show that the pair $\{w_1^*(\cdot), w_2^*(\cdot)\}$ can in fact be supported as the equilibrium outcome of the game, it is necessary to present a complete description of both the employer's and the worker's equilibrium strategy. Since doing so requires the introduction of a substantial amount of additional and uninteresting notation, it is best to describe only succinctly the nature of these strategies and refer any interested reader to Beaudry (1989). The simplest way to support self-enforcing contracts as an equilibrium outcome is to have the worker interpret any contract offer that does not satisfy (3) and (10) as being offered by the type Θ_L employer. In this case, any out-of-equilibrium contract offer will be accepted by the worker only if it is greater than $w_1^*(\Theta_L)$, since the worker will believe that the post-learning wage will be $w_2^*(\Theta_L)$ regardless of how w_2 is specified in the contract. Therefore, offering a contract that does not satisfy (3) and (10) is weakly dominated by the offer of $\{w_1^*(\Theta_L), w_2^*(\Theta_L)\}$. Furthermore, since the self-selection constraints ensure that a type $\tilde{\Theta}$ prefers to offer the contract $\{w_1^*(\tilde{\Theta}), w_2^*(\tilde{\Theta})\}$ to the contract $\{w_1^*(\Theta_L), w_2^*(\Theta_L)\}$, there is no deviating offer that can be profitable for the employer. Consequently, this updating rule for out-of-equilibrium offers allows self-enforcing contracts that satisfy (3) and (10) to be supported as a PBE.

Propositions 1 and 2 together provide a complete characterization of the self-enforcing contracts that can be supported as PBE of the game. However, there also may exist equilibria of the game in which the initial contracts are not respected.

Therefore, a brief justification for the exclusive focus on self-enforcing contracts is in order. All other Perfect Bayesian Equilibria of the game involve some pooling behaviour, whereby multiple types offer the same initial contract but then renege on their promised post-learning training wage. If the set of types was assumed to be finite instead of being a continuum, then standard refinements of Perfect Bayesian Equilibrium, such as Divinity (D1) or Never a Weak Best Response, can be used to eliminate these pooling equilibria, since the structure of the game ensures that the single crossing property is satisfied.[9] Therefore, in the case of a finite set of types, the unique equilibrium of the game is one where the initial contract is always respected in equilibrium. Although this refinement literature does not directly accommodate the case of a continuum of types, the result for a finite set of types offers a strong justification for focusing on self-enforcing contracts.

III. EMPIRICAL IMPLEMENTATION

The previous section derived a tight relationship between entry-level wages and post-learning wages, as stressed by equation (10). The objective of this section is to determine how to confront this prediction with data. Equation (10) can be interpreted as predicting that worker i's wage at time $t+\tau$, for a job he began at time t, will be equal to his entry-level wage, $w_{i,t}$, plus a wage profile that depends on the worker's market. The wage profile can vary between markets because the characteristics of a marginal job, Θ_L, may be different within each market. Assuming that market-specific profiles can be forecast based on a set of characteristics $X_{i,t}$, equation (10) can be restated as equation (12). In equation (12), $F^1(X_{i,t},\tau)$ represents the predictable part of the wage profile and ϵ represents the portion that is unpredictable by the econometrician:

$$w_{i,t+\tau} = F^1(X_{i,t},\ \tau) + w_{i,t} + \epsilon. \tag{12}$$

Under the assumptions of the model, equation (12) reflects the main empirical implications of the hypothesis that entry-level wages signal the credibility of future wages. These restrictions are (1) that the entry-level wage is a linear predictor of the future wage with a coefficient of 1 and (2) that the tenure profile $F^1(X_{i,t},\tau)$ is independent of the entry-level wage. In principal, these restrictions could be tested by estimating an unrestricted version of (12) and examining whether the coefficient on the entry-level wage is equal to 1. This would not be a powerful test of the model, however, since most other theories of wage determination also predict coefficients on $w_{i,t}$ that are close to 1. Therefore, it is necessary to reformulate the implications of this signalling model in a manner that accentuates its difference with other models. As will be shown, the restrictions implied by (12) can be differentiated from a full-commitment contract model once a worker's previous wage (w_P) is also included as a predictor of future wages.

9 See Bank and Sobel (1987) and Cho and Kreps (1987) for a presentation and a comparison of these refinements.

In the case where the employer can perfectly commit to a contract, it is optimal for him to set the post-learning wage equal to $\Phi_1 + \Theta$ to create efficient turnover decisions, and then to set the entry wage as low as possible given that the worker's participation constraint must be respected. Hence, it is always optimal for the employer to choose a full-commitment contract, denoted $\{w_1^c, w_2^c\}$, that satisfies the worker's participation constraint with equality. Equation (13) represents the worker's participation constraint. In (13), the wages $w_{R_{i,t}}$ and $w_{R_{i,t+\tau}}$ denote the worker's reservation wage at time t and $t+\tau$ respectively, and the function $W(w)$ represents the present discounted utility associated with a worker having the option of pursuing a job that pays w:

$$w_{1i,t}^c + \delta W(w_{2i,t+\tau}^c) = w_{R_{i,t}} + \delta W(w_{R_{i,t+\tau}}). \tag{13}$$

Taking a first-order approximation of (13) around $w_{R_{i,t+\tau}}$ and simplifying terms result in equation (14). Equation (14) states that the lower the entry-level wage relative to the worker's reservation wage, the higher the post-learning wage. This negative relationship reflects the well-known fact that when commitment is not a problem, a low-entry wage represents an investment by the worker which is compensated by a higher future wage.

$$w_{i,t+\tau}^c - w_{r_{i,t+\tau}} = -\psi(w_{i,t}^c - w_{r_{i,t}}), \text{ where } \psi = \frac{1}{W'(w_{r_{i,t+\tau}})}. \tag{14}$$

If it is further assumed that the worker's reservation wage at entry level is well approximated by the wage on his previous job and that it is recognized that this reservation wage would generally have grown over time because of the accumulation of general human capital, then (14) can be rewritten in the empirically more relevant form given by (15). In (15), the function $F^2(X_{i,t}, \tau)$ represents the average growth in general human capital over a period of length τ for an individual with characteristics $X_{i,t}$, and ϵ_2 represents the person-specific growth in human capital:

$$w_{i,t+\tau}^c = F^2(X_{i,t},\ \tau) - \psi w_{i,t}^c + (1+\psi) w_{P_{i,t}} + \epsilon_2. \tag{15}$$

It is important to note that equation (15) is a valid interpretation of the full commitment model only if observations on $w_{t+\tau}^c$ are taken after the learning period is completed. In this case, the return associated with the acceptance of an initially low wage should be completely reflected in the $t+\tau$ wage. In contrast, if the observations on $w_{t+\tau}^c$ are taken before the training period is completed, the $t+\tau$ wage incorporates only part of the return from the initial investment. In this case, the appropriate prediction of the full-commitment model is that within-job wage growth is negatively related to the wage change at job change, since the returns from the initial investment are still being integrated into the wage. In other words, with a full-commitment contract, the smaller the increase in wage at the beginning of the job the larger the expected increase in wage over any given period. Equation (16) represents this prediction of full-commitment contract.

$$w_{i,t+\tau}^c - w_{i,t}^c = F^2(X_{i,t},\ \tau) + \tilde{\psi}(w_{i,t}^c - w_{P_{i,t}}) \cdot \tau + \epsilon, \text{ where } \tilde{\psi} < 0. \tag{16}$$

In order to embed the predictions of both the self-enforcing contract model (equation (12)) and the predictions of the full-commitment model (equations (15) and (16)) into a linear regression model, it is necessary to choose a functional form for $F^1(\cdot)$ and $F^2(\cdot)$. Equation (17) represents such a regression model when the $F(\cdot)$ functions are assumed to be quadratic in tenure:

$$w_{i,t+\tau} = \alpha_0 + \alpha_1 w_{i,t} + \alpha_2 w_{P_{i,t}} + \alpha_3 (w_{i,t} - w_{P_{i,t}}) \cdot \tau + \alpha_4 \tau + \alpha_5 \tau^2 + \alpha_6 X_{i.t} \cdot \tau + \epsilon. \qquad (17)$$

Equation (17) expresses the post-entry wage (observed after a worker has been τ periods on the job) as both a linear combination of the entry-level wage and the worker's previous wage and as a function of a tenure profile. The tenure profile in (17) is allowed to depend on the wage change observed at job change and on characteristic $X_{i,t}$. Equations (12), (15), and (16) all can be viewed as placing restrictions on the coefficients of equation (17). In the case of self-enforcing contracts, the model's prediction regarding entry wages signalling post-entry wages implies that α_1 should be equal to 1 and that α_2 should be equal to zero. This joint hypothesis will be referred to as the signalling hypothesis. Moreover, the theory also implies that the tenure profile is independent of the wage change at job change and therefore α_3 is predicted to be equal to zero. This hypothesis will be referred to as the independence hypothesis. Testing the combined hypothesis that $\{\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0\}$ represents a rather simple and thorough way to evaluate the potential relevance of the theory developed in section 2.

The restrictions on (17) implied by assuming full-commitment contracts were presented as depending on whether the observations on $w_{i,t+\tau}$ were taken before or after the learning period was completed. If τ is longer than the learning period, equation (15) implied that $\alpha_1 = -\psi$, $\alpha_2 = (1 + \psi)$, and $\alpha_3 = 0$. Alternatively, if τ is shorter than the learning period, equation (16) implied that $\alpha_1 = 1$, $\alpha_2 = 0$ and $\alpha_3 < 0$.[10] In either case, the self-enforcing contract model should be rejected if the full-commitment contract model is a better description of wage determination.

Before for estimating equation (17), it is instructive to briefly discuss how other theories of wage determination can be compared with the signalling contract model. The two theories that seem most relevant are the learning model and the matching model.[11] In both these cases, the standard theory indicates that wages will follow a random walk and therefore predict a pattern of coefficients in (17) that is similar to the self-enforcing contract model.[12] In this sense, tests based on equation (17)

10 An incentive model with full-commitment contracts, like that discussed by Lazear (1979), also has the prediction that $\alpha_1 = 1$, $\alpha_2 = 0$, and $\alpha_3 < 0$.

11 It would also be instructive to compare the model with other efficiency-wage models. However, these models are not developed in a manner in which they can easily be interpreted in terms of equation (17). One exception is the dual labour market hypothesis (Doeringer and Piore 1971) which explicitly predicts that α_3 should be greater than zero; that is, it is argued that good jobs pay higher entry-level wages and have steeper wage profiles.

12 See Jovanovic (1979) for the matching model and Farber and Gibbons (1990) for the learning model.

are not a powerful means of discriminating between this class of theories. Both the matching model and the learning model also imply that there is no real tenure-profile associated with jobs, however, and therefore these models are inconsistent with the observed positive tenure profiles in the early stages of employment relationships. In this sense, the self-enforcing contract model differentiates itself from both the matching and the learning model by allowing wages to follow a random walk with a drift that is a function of tenure.

To sum up the predictions: (1) the full-commitment model predicts $\{\alpha_1 < 0, \alpha_2 > 1, \alpha_3 = 0\}$ if observations on $w_{i,t+T}$ are taken after learning is completed; otherwise it predicts that $\{\alpha_1 = 1, \alpha_2 = 0, \alpha_3 < 0\}$; (2) the signalling contract model predicts that $\{\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0\}$ whether or not observations on $w_{i,t+T}$ are taken after learning is completed, since it predicts on-the-job wage changes to be independent of wage change observed at entry.[13]

IV. EVIDENCE

1. The data

The estimation of equation (17) requires data that follow individuals over at least two jobs. The National Longitudinal Survey Youth Cohort (NLSY) is especially well suited for this purpose, since younger workers are known to change jobs frequently. Moreover, the NLSY data seem particularly relevant for the current study, since the informational imperfections assumed in section II are more likely to be prevalent in the market for young workers. Therefore the data used for estimation are based on individuals in the NLSY (1979–85) who held at least two full-time jobs (more than thirty hours per week) after no longer being full-time students. The intervening time between jobs was limited to a maximum of a year. The analysis concentrates on the profiles in the second job. Wages are measured in 1979$, using the CPI as a deflator. Owing to the survey's questioning procedure, jobs that last less than a year have only one wage observation. The sample was therefore restricted to jobs with tenure greater than a year. Once all observations with missing values are eliminated, the initial data set contains 401 observations on second-job wage profiles.[14] Summary statistics appear in table 1.

2. The results

Estimates of equation (17) are presented in table 2. The dependent variable is the wage at the end of a worker's second job. Column 1 presents estimates for the complete sample, and column 2 presents those for a sample with tenure restricted to be greater than seventy-five weeks. This sample split is based on Brown's (1989) observation that most workers consider the learning phase associated with their job

13 Formally, the model developed in section II forces wages to be constant over the training period. However, the spirit of the model suggests that during the training period wages could rise in accordance with the optimal tenure profile (under symmetric information) of the job of type Θ_L.

14 The relatively small size of the sample reflects the fact that turnover among young workers is extremely high and that most jobs held early in life do not last more than a year.

TABLE 1
Characteristics of sample members

Variable	Mean	Std Dev.
Real hourly wage, previous job (1978 $)	3.28	1.46
Real wage, beginning of job	3.58	1.64
Real wage, end of job (or at end of survey)	4.00	2.05
Job tenure (weeks) end of job (or end of survey)	108.9	49.1
Years of schooling	12.99	1.89
Percentage female	53	
Percentage non-white	41	
Sample size	401	

to be completed within the first year to a year and a half. Therefore, column 2 is very likely to represent only observations on $w_{i,t+T}$ that are taken after the learning period is completed. Columns 1b and 2b exclude all observations where wages are determined by collective bargaining. The test statistic for the joint hypothesis $\{\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0\}$ is presented at the bottom of table 2 under the heading T_1. In none of the four cases is T_1 rejected at the 95 per cent confidence level. Moreover, none of the coefficients on α_1, α_2, and α_3 is individually different from the restrictions imposed by T_1. Columns 1b and 2b give similar results to those in columns 1 and 2. Hence, wages determined by collective bargaining are not the driving force behind the results. This fact is important, since the test T_1 is based on a model formulated mainly for decentralized environments.

The test statistic associated with the hypothesis $\{\alpha_1 = 1, \alpha_2 = 0\}$ (the wage-signalling hypothesis) is also presented in table 2 under the heading T_2. This test is more easily accepted by the data than T_1. Given that the data are allowed to select any linear combination of $w_{i,t}$ and $w_{P_{i,t}}$ in order to predict $w_{i,t+T}$, it is somewhat surprising that the point estimates place virtually all the weight on $w_{i,t}$ as suggested by the signalling hypothesis. The non-rejection of both T_1 and T_2 suggests that the data are unlikely to have been generated by the full-commitment contract model with short learning periods, since this model predicts $\alpha_1 < 0$ and $\alpha_2 > 1$, which is clearly at odds with the data.

Column 3 presents an estimate of α_3 for the case where α_1 and α_2 are restricted to be 1 and 0, respectively (which correspond to the restrictions tested by T_2). The imposition of this restriction is equivalent to changing the dependent variable to $w_{i,t+T} - w_{i,t}$. The estimate of α_3 in column (3) is again not significantly different from zero at conventional levels, but, more surprisingly, it is also smaller in magnitude than that estimated in column 1. In particular, the point estimate of $\alpha_3 = 0.046$ implies that it would take more than eight years for an initial wage differential of 10 per cent, evaluated at the mean of the sample, to be reversed. The fact that α_3 is estimated to be smaller than zero suggests that the data are consistent with the

TABLE 2

Variables	(1)	(1*b*)	(2)	(2*b*)	(3)
Constant	0.025	0.04	0.22	−0.08	−0.32
	(0.47)	(0.47)	(1.03)	(1.17)	(0.41)
α_1	1.04	1.02	0.98	0.85	1.00
Entry wage	(0.14)	(0.15)	(0.23)	(0.27)	
α_2	−0.14	−0.08	−0.17	−0.06	0.00
Previous wage	(0.14)	(0.15)	(0.23)	(0.27)	
α_3	−0.08	−0.08	−0.08	−0.05	−0.046
$(w_1 - wp) \cdot \tau$	(0.06)	(0.07)	(0.09)	(0.10)	(0.026)
α_4	0.64	0.26	0.73	0.85	0.66
Tenure	(0.39)	(0.41)	(0.73)	(0.84)	(0.39)
α_5	−0.04	−0.01	−0.05	−0.09	−0.06
Tenure sq	(0.07)	(0.07)	(0.12)	(0.14)	(0.07)
$\alpha_{6,1}$	0.03	0.05	0.04	0.05	0.02
school-12 $\cdot \tau$	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
$\alpha_{6,2}$	0.04	0.08	0.06	0.07	0.03
(exp-1) $\cdot \tau$	(0.04)	(0.04)	(0.05)	(0.06)	(0.04)
$\alpha_{6,3}$	0.06	0.05	0.09	0.13	0.07
(non white) $\cdot \tau$	(0.06)	(0.06)	(0.07)	(0.09)	(0.06)
$\alpha_{6,4}$	−0.18	−0.13	−0.22	−0.22	−0.16
(female) $\cdot \tau$	(0.06)	(0.07)	(0.08)	(0.09)	(0.06)
R^2	0.50	0.51	0.47	0.43	0.50
Nb. obs.	401	327	256	214	401
T_1	2.13	2.24	2.41	2.34	
	(3,379)	(3,305)	(3,234)	(3,192)	
T_2	1.57	0.47	2.46	1.96	
	(2,379)	(2,305)	(2,234)	(2,192)	

NOTES:
Dependent variable: Real wages at end of second job
Standard errors are in parentheses.
The estimated occupation and industry dummies are omitted.
F-statistics are given for the tests with degrees of freedom in parentheses.

full-commitment contract model with long learning periods. However, the point estimate of α_3 makes it hard to believe that initially low wages are compensated by faster wage growth, as would be the case with full-commitment contracts.

One reason why the data may indicate a very low catch-up effect (α_3 close to zero) is that they do not focus enough on the longer tenures in which the returns to firm-specific investment should be more noticeable. In particular, this would be the case if Brown's observation on the length of the learning period is a gross underestimate (or if a Lazear (1979) type incentive model was the appropriate alternative). In order to examine this possibility, it is helpful to rewrite equation (17) under the assumption that $\alpha_1 = 1$ and $\alpha_2 = 0$. Subtracting $wp_{i,t}$ from both

TABLE 3

Variables	(4)	(5)	(6)	(7)
Constant	0.20 (0.52)	0.49 (0.78)	1.81 (1.09)	0.92 (0.81)
$(w_1 - wp)$	0.99 (0.06)	1.01 (0.10)	0.72 (0.18)	0.83 (0.13)
(school-12)	0.16 (0.05)	0.19 (0.08)	−0.09 (0.13)	0.05 (0.08)
(exp-1)	0.17 (0.08)	0.17 (0.16)	−0.15 (0.27)	0.30 (0.22)
(non white)	−0.17 (0.15)	−0.07 (0.28)	0.35 (0.47)	0.07 (0.30)
(female)	−0.18 (0.06)	−0.13 (0.07)	−0.22 (0.08)	−0.22 (0.09)
R^2	0.57	0.50	0.40	0.61
Nb. obs.	239	135	78	81

NOTES:
Dependent variable: Change in real wages since previous job $(w_{1,t+\tau} - wp_{i,t})$
Standard errors are in parentheses.
The estimated occupation and industry dummies are omitted.

sides of this equation leads to equation (18), where now the dependent variable is $(w_{i,t+\tau} - w_{P_{i,t}})$:

$$(w_{i,t+\tau} - w_{P_{i,t}}) = \alpha_0 + (1 + \alpha_3 \cdot \tau)(w_{i,t} - w_{P_{i,t}}) + \alpha_4\tau + \alpha_5\tau^2 + \alpha_6 X_{i.t} \cdot \tau + \epsilon. \tag{18}$$

The restriction on (18) implied by the signalling contract model is that the coefficient on $(w_{i,t} - w_{P_{i,t}})$ is equal to 1 as long as the observations on $w_{i,t+\tau}$ is taken after the learning period is complete. Table 3 presents estimates of equation (18) for subsamples grouped by tenure. Columns 4 through 7 report the results for subsamples restricted to years of tenure between 1 and 2, 1.5 and 2.5, 2.5 and 3.5, and 3 and 5, respectively. Note that in table 3 tenure is omitted, since it is considered constant within each sample. The results of table 3 indicate that the coefficient on $(w_{i,t} - w_{P_{i,t}})$ is very close to one for short tenures, but they show some sign (not significantly) of drifting below 1 for longer tenures.[15]

Even for longer tenures, however, the point estimates still offer very limited support for the full-commitment contract model, since they indicate that an initial

15 Selectivity could cause the estimates of the coefficient for $(w_{i,t} - w_{P_{i,t}})$ to have a bias towards zero, which would only strengthen the maintained hypothesis that this coefficient is actually one. In Beaudry (1989) this selectivity issue is explored but is not found to change the results significantly.

reduction in wages is compensated only by approximately 20 per cent after three to five years on the job.

Overall, the data provide suggestive evidence in favour of the hypothesis that entry-level wages signal the credibility of future wages. In contrast, interpreting the data as generated by the full-commitment contract model with long learning periods seems tenuous given the low speed at which the returns from firm-specific investment are estimated to materialize.

V. CONCLUSION

Of all the efficiency wage models, the turnover model is possibly the oldest, the most intuitive, and one of the most widely regarded as being a major cause of unemployment. However, it is also the model with the weakest choice theoretic foundations. This paper takes a step towards improving our understanding of why turnover considerations may lead to the payment of efficiency wages by extending the standard model to a case where entry-level wages are set to signal the credibility of post-entry wages. One of the appealing features of the model is that the signalling equilibrium has a simple and intuitive structure, that is, entry wages signal future wages in a ratio of one-to-one. Moreover, the evidence examined in the paper provides suggestive evidence in favour of the hypothesis, which is encouraging both for the particular model and for the more general approach of modelling economic behaviour as the outcome of a game of asymmetric information.

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