The Signaling Role of Note Being Promoted: Theory and Evidence

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Abstract

This article studies the negative signals associated with non-promotion. I first show theoretically that, when workers' productivity rises little with additional years on the same job level, the negative signal associated with non-promotion leads to wage decreases. On the other hand, when additional job-level tenure leads to a sizable increase in productivity, workers' wages increase. I test my model's predictions using the personnel records from a large US firm from 1970-1988. I find a clear hump-shaped wage-job-tenure profile for workers who stay in the same job level, which supports my model's prediction.

Keywords: Asymmetric Information, Human Capital Accumulation, Signaling, Promotion, Wages

JEL: J24, J31, M51

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Promotion sends positive signals about a worker's ability and productivity. This theoretical possibility has been extensively studied in a body of literature stemming from Waldman (1984a). Waldman assumes that a worker's current employer has better information about a worker's true ability from observing this worker at work. Potential employers can only infer the worker's ability by observing her current period's job assignment made by her current employer. Waldman's two main conclusions are (1) promotions send positive signals about workers' abilities and thus are associated with substantial wage increases; (2) firms promote fewer employees than what is socially optimal and this distortion is more severe when workers' human capital is general rather than firm specific.

While the signals associated with promotion have been extensively examined, the signals associated with non-promotion, on the other hand, are surprisingly understudied. In this article, I extend the promotion-as-signal framework by arguing that additional years of job-level tenure (i.e., non-promotion) sends negative signals about a worker's ability. Intuitively, if a worker stays in the same job level for many years while her peers are all promoted, this worker is believed to be less competent (or is less likely to be a productive worker). These negative beliefs eventually translate into small wage increases or even wage decreases.

Although the basic idea is intuitive, formal theoretical models that explore this negative signaling idea are almost non-existent. Bernhardt (1995) is the only previous study that captures the negative signals associated with not being promoted. In that study, Bernhardt argues that there is a negative sorting in promotion such that abler workers are promoted earlier. However, that analysis makes ambiguous predictions regarding the implications of the negative sorting for workers' wage dynamics. In this article, I build a T-period model with two job levels to explore the negative signaling role of non-promotion on workers' wage dynamics.

My model shows that when a worker stays in the same job level for a long time, her wages first increase then decrease with additional job-level tenure. To see the logic, consider a set up where a worker's productivity is jointly determined by her expected ability and on-the-job human capital accumulation. Firms use non-promotion as signals to infer workers' abilities. If firms keep on receiving negative signals about a worker's ability from non-promotion, this worker is perceived less likely to be a productive worker. The negative signals associated with additional job-tenure eventually cause the non-promoted workers' wages to fall since productivity rises little with additional job-level tenure after the worker spends a long time on the same job. But since human capital accumulates very fast when a worker first starts on a job, the fast human capital accumulation outweighs the downward adjustment (due to non-promotion) in beliefs about a worker's expected ability and therefore the non-promoted workers' wages rise with job-tenure even though there is negative learning about their abilities.

From the above reasoning, if one only considers the learning component in the wage determination process, wages should decrease with additional job-tenure. On the other hand, if one only considers the human capital component, wages should increase then flatten out with additional tenure on the same job. By bringing together the learning argument and human capital theory, I can explain two wage patterns observed in Baker et al. (1994a). First, pre-promotion wages increase then decrease with job-level tenure. Second, the wages in the periods of promotion increase then decrease with job-level tenure on the lower level job.

This article contributes to the literature in several different ways. First, it fills a gap in the learning literature by capturing the negative signaling role of non-promotion. Second, it contributes to the human capital literature by exploring the relationship between wages and job-level tenure. Third, it provides an explanation for a set of empirical findings that are not well captured in existing models. It also provides empirical evidence that is consistent with my model's predictions.

The outline of the article is as follows. The next section reviews the related literature. Section 2 sets up the model. In Section 3, I first analyze a T-period model with full information then compare equilibrium behavior in this benchmark model to equilibrium behavior in a model with asymmetric information. I present empirical evidence in Section 4. Section 5 concludes.

1 Related Literature

This article connects two theoretical building blocks in the existing literature on wage and career dynamics inside firms - learning and on-the-job human-capital accumulation.

The learning literature falls into two broad categories. One set of papers assumes symmetric learning where workers' outputs are observed by all firms in the market (Harris and Holmstrom, 1982). The other set of papers assumes asymmetric learning where a worker's current employer privately observes the worker's output. The asymmetric learning literature further divides into two areas of focus. One set of papers investigates the adverse selection issue in labour market turnover following Greenwald (1986). The other set of papers explores the idea of promotions as signals following Waldman (1984a). My paper builds on the promotion-as-signal approach under asymmetric learning.

The promotion-as-signal approach has been extended in many different ways. Ricart-i-Costa (1988) considers a two-period n-job-level model. Bernhardt (1995) considers a two-level model with infinite periods. In Zabojnik and Bernhardt (2001), a promotion signal contains information about workers' human-capital investment rather than their innate ability. DeVaro and Waldman (2012) consider how promotion signals vary with education.[1] The promotion-as-signal approach has also been extended to analyze up-or-out contracts and turnover (Bernhardt and Scoones, 1999; Ghosh and Waldman, 2010).

While Waldman (1984a) and the various extensions capture many stylized facts about wage and promotion dynamics, such as large wage increases upon promotion (Bernhardt, 1995) and the wage-and-firm-size effect (Zabojnik and Bernhardt, 2001), etc., these studies have almost exclusively focused on the positive signals associated with promotion. My paper fills a gap in the learning literature by exploring the negative signals associated with non-promotion.

Another important perspective concerning workers' wage and career dynamics inside firms is on-the-job human-capital acquisition. Numerous empirical studies have investigated the contribution of firm tenure and total labour market experience to individuals' wage growth and find a concave wage-firm-tenure profile using household surveys (Altonji and Shakotko, 1987; Topel, 1991; Altonji and Williams, 2005; Sullivan, 2010; Pavan, 2011).[2] On the other hand, using a 1% sample of the

[1] DeVaro and Waldman (2012) treat education as a measure of initial human capital stock, not as another source of signals.

[2] Sanders and Taber (2012) provide a comprehensive survey of the literature on life-cycle wage growth and heterogeneous human-capital accumulation.

British labour force, Devereux et. al. (2013) find a hump-shaped relation between wages and job-tenure when they do not control for firm-tenure.[3] Using firms' personnel records, Baker at al. (1994a) also find a hump-shaped wage-job-tenure profile for non-promoted workers, i.e., their wages first increase with job-tenure then decrease.

While the standard human capital accumulation theory explains the increase of wages with job-tenure when workers are new to a job, it does not explain why wages fall when workers stay on the same job for a long time. The asymmetric learning framework with human capital accumulation in Waldman (1984a) might potentially explain the hump-shaped wage-job-tenure relation, however, neither the original '84 model nor most of the later extensions in the promotion-as-signal literature capture the negative signals of non-promotion. There are two reasons. First, those models assume that a worker's current employer learns about the worker's ability perfectly after one period of employment. Second, many of those models have a strong "winner's curse" in their equilibrium (Milgrom and Oster, 1987). In models with asymmetric learning, firms only observe the job assignments of the workers at other firms (they observe the output of their own workers). When the winner's curse occurs, the wage offer that a firm is willing to make to a non-promoted worker at another firm is determined by the lowest possible expected ability level among workers with the same job assignment history. Furthermore, this lowest expected ability does not vary with job-level tenure for the non-promoted worker if the cur-

[3]They find a negative relation between job tenure and wages holding firm tenure constant. But in their study, they do not control for levels and they do not distinguish between promoted workers and non-promoted workers. So the negative relation between job tenure and wages may capture the wage difference between the promoted workers who have very short job-tenure and the non-promoted workers who in general have longer job-tenure in the current job.

rent employer learns the worker's ability perfectly after a period. Thus, the signal associated with non-promotion does not cause further adjustments in wage offers to previous employees and thus wages actually paid.[4] My model moves away from the strong winner's curse problem by assuming the existence of exogenous turnover as in Greenwald (1986). With exogenous movers, outside firms are willing to offer wages that are above the expected productivity of the lowest ability worker with a certain job assignment history. That is, there are further adjustments in wages when a non-promotion is observed.

The only previous paper that captures negative signals associated with non-promotion is Bernhardt (1995). Bernhardt considers a framework with human capital accumulation and asymmetric learning without the winner's curse. However, his model predicts that the non-promoted workers' wages can either increase or decrease with additional tenure but the relationship is monotonic. In addition, Bernhardt focuses on the relationship between wages and firm-tenure. However, the household surveys show that workers' wages do not fall overall with firm-tenure. As shown in Baker et al. (1994a), workers' wages only fall with job-tenure when they stay a long time on the same job level.

In summary, most of the existing promotion-as-signal models do not capture the negative signals of non-promotion. The only theoretical model capturing this idea makes predictions that do not match the evidence. By combining the asymmetric learning argument and human capital theory, I develop a tractable framework to

[4]In Waldman (1984a), the output on the lower level job is assumed to be a constant. Thus, we should observe wages stay constant with additional job tenure. In the later extensions of Waldman (1984a), workers' outputs are determined by their expected abilities and human capital levels. With a strong winner's curse, we should observe wages increase with tenure in those models due to human-capital accumulation because a non-promoted worker's expected output is independent of her ability.

capture a set of empirical findings in Baker et al. (1994a). In particular, Baker et al. show that, for a worker who stays in the same job level for more than six years, her wages first increase then decrease. In addition, if a worker earns a promotion within four or five years of entering into a job level, her wage in the period of promotion is higher than the promotion wage paid to a worker who was promoted in the previous period. But if the promotion is more than four or five years after entering into the job level, her wage upon promotion is lower than the promotion wage paid to a worker who was promoted in the previous period.

2 The Model

In this section, I set up a T-period model to analyze the role of non-promotion on workers' wage dynamics.

There is free entry into the market. All firms are identical with two job levels. The manager jobs (m) are on the upper level and the labourer jobs (l) are on the lower level .

Workers enter the labour market in period 1. They are either good (g) or ordinary (r). Let A denote workers' ability types, i.e., $A \in \{g, r\}$. Neither the firms nor the workers themselves observe the true type of a particular worker. However, their prior belief is that a worker is good with probability p_0. I assume p_0 is sufficiently small that, given the production function defined below, all workers are assigned to the labourer job in period 1.

Outputs are jointly determined by workers' ability types and their human capital levels. Firms learn about workers' types gradually by observing workers' output realizations. This is a generalization of the setting in previous papers such as Waldman (1984a) and Bernhardt (1995) where a worker's current employer learns about the worker's ability perfectly after a single period of employment. Human capital accumulates deterministically with tenure.

In each period, worker i attains high (H) productive efficiency with probability $\theta_i = \theta_A \in \{\theta_g, \theta_r\}$ and low productive efficiency with probability $1-\theta_i$. That is, a worker's ability type affects the probability of attaining high productive efficiency and a good worker attains high productive efficiency with a higher probability, i.e., $\theta_g > \theta_r$. The high or low production efficiency translates into different output realizations on different job levels. To be specific, worker i's output in period t if she is assigned to job j is

$$y_{it}^{j} = \begin{cases} (1+s_t)[z_H^j + f(x_{it})] & \text{with prob. } \theta_i \\ (1+s_t)[z_L^j + f(x_{it})] & \text{with prob. } (1-\theta_i),\, j \in \{l,m\}. \end{cases} \tag{1}$$

I assume $z_H^m > z_H^l > z_L^l > z_L^m > 0$. This set up captures that the manager job has greater returns to the high productive efficiency but the labourer job has greater returns to the low productive efficiency. It also follows the standard assumption in the job assignment literature as in Sattinger (1975) and Rosen (1982) that the manager job has greater marginal returns to an increase in the productive efficiency from low to high.

In addition, I assume that a good worker is on average more productive on the manager job than on the labourer job but an ordinary worker is on average more productive on the labourer job than on the manager job. Let $E_A^j = \theta_A z_H^j + (1-\theta_A) z_L^j$, $A \in \{g,r\}$. Then $E_g^m > E_g^l$ and $E_r^l > E_r^m$. This set up means that a good worker has a comparative advantage producing as a manager but an ordinary worker has a comparative advantage producing as a labourer (although a good worker is always more productive than an ordinary worker on both jobs, i.e., $E_g^j > E_r^j, j \in \{l,m\}$). Therefore, firms have an incentive to (correctly) assign a good worker to a manager position and an ordinary worker to a labourer position.

I refer to a worker's previous period's employer as the incumbent firm and all other firms as outside firms. Let q_{it}^{INC} denote an incumbent firm's belief in period t that worker i is good based on her output history.[5] Since the speed of learning on the lower level and the upper level job is the same, the belief that a worker is good is a function of whether or not a worker attains high (low) productive efficiency only. That is, at which job level she has worked is irrelevant. In addition, given the binary ability types, only the total number of high (or low) productive efficiencies that a worker attains matters for the belief in a given period. Let h_i^{t-1} denote the total number of high productive efficiencies that worker i has attained up to period $t-1$. The expected output of worker i who is believed to be good with probability $q_{it}(h_i^{t-1})$ and who is assigned to job j in period t is

$$\begin{aligned} E[y_{it}^j | q_{it}^{INC}(h_i^{t-1})] &= (1+s_t)\{q_{it}^{INC}(h_i^{t-1})[\theta_g z_H^j + (1-\theta_g) z_L^j] \\ &\quad + [1-q_{it}^{INC}(h_i^{t-1})][\theta_r z_H^j + (1-\theta_r) z_L^j] + f(x_{it})\} \\ &= (1+s_t)\{q_{it}^{INC}(h_i^{t-1}) E_g^j + [1-q_{it}(h_i^{t-1})] E_r^j + f(x_{it})\}, j \in \{l,m\}. \end{aligned} \tag{2}$$

x_{it} is worker i's labour market experience up to period t. $f(\cdot)$ is the human

[5] Outside firms' beliefs about workers' ability types are based on workers' job assignments at their incumbent firms. I will discuss in more detail about how outside firms' beliefs are determined in equilibrium in the next section.

capital accumulation function. Following Acemoglu and Pischke (1998), I assume f to be twice continuous differentiable, strictly increasing, concave with $f(0) \geq 0, \lim_{x \to 1} f^{'}(x) = \infty$ and $\lim_{x \to \bar{t}} f^{'}(x) = 0$ for some $2 \leq \bar{t} \leq T-1$. That is, human capital accumulates very fast when tenure is low. When tenure is higher than $\bar{t}$, human capital almost stops growing with additional tenure. The human capital accumulation function enters into the production function additively to the part of the output that is determined by workers' innate abilities.

$s_t = S > 0$ if a worker is employed by her previous period's employer in period t. $s_t = 0$ otherwise. s_t thus captures firm-specific human capital. Following Bernhardt (1995), I assume that once a worker leaves her previous employer, her previous employer becomes a new firm to her and cannot collect the firm-specific human capital anymore unless she comes back and works for her previous employer for another period. This assumption guarantees that in each period only one firm can collect the firm-specific human capital from a worker's productivity. This means that workers do not have an incentive to constantly change employers to enable the firm-specific human capital in multiple firms. In practice, it is possible that after an employee leaves a firm, the firm' policy, structure, or business practices change such that the previous firm-specific human capital is not applicable when this employee re-enters the firm.

There is a cutoff belief that a worker is good, q^*, such that the expected output on level l and that on level m are equal. Note that the equal-productivity cutoff at an outside firm is equal to the equal-productivity cutoff at an incumbent firm.[6]

[6] In general, if the firm-specific human capital term is not multiplicative in the production function, the equal-productivity cutoff ability levels are different in an incumbent firm and in an outside firm.

q^* solves $q^* E_g^l + (1-q^*)E_r^l = q^* E_g^m + (1-q^*)E_r^m$, $q^* = (E_r^l - E_r^m)/[(E_g^m - E_r^m) - (E_g^l - E_r^l)]$. Thus, if the belief that a worker is good in period t is above this cutoff level, she is expected to be more productive on the management job; otherwise, she is expected to be more productive on the labourer job.

Following Greenwald (1986), I assume that a small fraction, λ, of workers leave the incumbent firm for exogenous reasons in each period. The existence of exogenous job switchers alleviates the winner's curse problem as discussed in the previous section.[7] I consider equilibrium behavior when $\lambda \to 0$.

To keep the model tractable, I focus on parameterizations that satisfy the following two conditions.

(i) $q^* < q_{iT}(1)$. This condition says that if worker i attains only one high productive efficiency in any of the previous $T-1$ periods, she is more productive on the upper-level job in period T. Therefore, there are no demotions in equilibrium.

(ii) S is "large". In particular, I assume that S is large enough (the precise parameter restriction can be found in the Appendix) that, in period T, the incumbent firm has an incentive to assign a worker with only one high output realization up to period $T-1$ to the upper level job. This condition guarantees that a worker is promoted when a high productive efficiency is attained. It also means an incumbent firm's belief about a non-promoted worker's ability type based on realised outputs is the same as an outside firm's belief about this worker's ability type based on observed job assignments. It guarantees that there is promotion in every period and

[7] Note that the exogenous job-switching status is different in every period, i.e., an exogenous mover in this period might not be an exogenous mover in the next period. As I will show, in equilibrium, there is no turnover other than the exogenous job-movers. If the job-switching status is time-invariant, once a worker moves, she reveals her true job-switching type such that the firm can separate the exogenous movers from other workers perfectly. As a result, I would have the strong winner's curse for the non-exogenous movers at the beginning of period 3.

there is no distortion in firms' promotion decisions.

Firms and workers are risk neutral and discount the future with a common discounting factor $\beta < 1$. There is no cost to workers from changing firms or to firms from hiring or firing workers. Under these assumptions, long-term contracts are not necessary, so I consider equilibrium wages that are determined by spot-market contracts. At the beginning of each period, firms engage in a wage-setting game where they place wage "bids" in order to attract workers. That is, wages are promised before production begins in each period.

The timing of the events is the following. At the beginning of period 1, nature moves first to assign an ability type to each worker and this ability type is time invariant. Firms make period-1 job assignments and wage offers conditional on their prior beliefs' about a worker being good. Workers choose the firm with the highest wage offer to work at. At the end of period 1, incumbent firms privately observe workers' outputs. At the beginning of the next period, incumbent firms update their beliefs about workers' ability types and announce job assignment decisions for their previous period's employees. After outside firms observe these job assignment decisions, all firms make wage offers simultaneously. Workers privately learn about their job-switching types in this period and the exogenous movers depart. Workers then choose the firm with the highest wage offer to work at. If there are multiple firms offering the same highest wage, a worker chooses randomly among those highest-wage-offer firms but stays with her previous period's employer if her previous period's employer is one of the highest-wage-offer firms. Production then begins. At the end of period 2, workers' outputs are privately observed by their incumbent firms. This process repeats until date T.

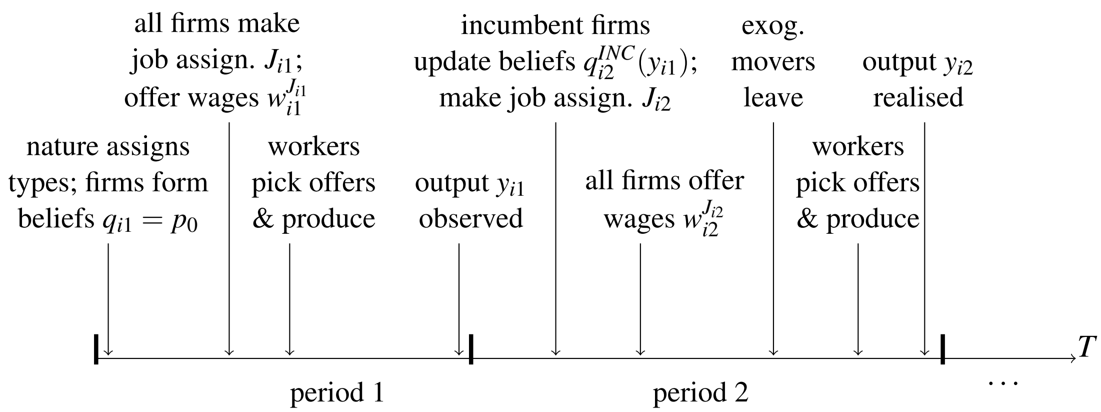

Figure 1: Timing of the job-assignment-wage-offer game.

Firms' strategies are sequences of job-assignment and wage-offer pairs. Let w_{it}^{j} denote the wage offer to worker i in period t. J_{it} denotes the job assignment to worker i in period t. In equilibrium, the incumbent firm anticipates that outside firms' behavior would be affected by its promotion decisions. The best response is to match the wage offer from outside firms and extract the rent created by the firm-specific human capital. Therefore, the equilibrium wage offer from the incumbent firm is equal to the wage offer from outside firms and there is no turnover in equilibrium except for the exogenous movers. A firm's strategy set is

$$\left\{J_{it}, w_{it}^{j}\right\}_{t}, j = J_{it} \in \{l, m\}, t \in \{1, \ldots, T\}.$$

Figure 1 shows the sequences of beliefs, job assignments, and wage offers after the incumbents observe the outputs of their own workers in each period.

3 The Analysis

In this section, I begin the analysis with a brief discussion about the equilibrium job assignment rules and wage offers when a worker's type is perfectly known. I then consider what happens given asymmetric information and discuss the relationship between non-promotion, negative signals, and wage dynamics.

3.1 A Full-information model with T periods

Under full information, workers' types are fully observed by all firms. Each firm's problem is to assign workers to the jobs that maximise the total discounted profit. Firms solve different problems when assigning workers who have worked for them in the previous period and those who have not. This is because firms can collect firm-specific human capital from the old workers in the current period but they have to train new workers.

Consider a firm's problem when it assigns workers who were employed by the firm in the previous period, i.e., when the firm makes job assignment decisions and wage offers as an incumbent firm. Let $\Pi_t^{INC}(\theta_i)$ denote the incumbent firm's profit in period t from employing a worker who has a probability θ_i of attaining the high productive efficiency. $\Pi_t^l(\theta_i)$ is the non-promotion profit and $\Pi_t^m(\theta_i)$ is the promotion profit from employing this worker. Then $\Pi_t^{INC}(\theta_i) = \max\left\{\Pi_t^l(\theta_i), \Pi_t^m(\theta_i)\right\}$,[8]

[8]Since there is no turnover in equilibrium for non-exogenous movers and the probability of exogenous moving approaches zero, firm-tenure is equal to their total labour market experience in t. Also, I only have two job levels in the current set up. For those who are not promoted and who do not move to other firms, their labour market experience, firm-tenure, and job-tenure are the same. For the promoted workers in the period of promotion, their labour market experience, firm-tenure and job-tenure are also the same. However, the negative signals are embedded in the job-tenure. I will discuss how to extend the framework to distinguish between the three after I analyze the model.

where

$$\Pi_t^l(\theta_i) = (1+S)[\theta_i z_H^l + (1-\theta_i) z_L^l + f(t-1)] - w_{it}^l + \beta \Pi_{t+1}^{INC}(\theta_i), \quad (3)$$

$$\Pi_t^m(\theta_i) = (1+S)\,[\theta_i z_H^m + (1-\theta_i) z_L^m + f(t-1)] - w_{it}^m + \beta \Pi_{t+1}^{INC}(\theta_i). \quad (4)$$

w_t^j is the equilibrium wage that an incumbent firm offers, which is equal to outside firms' wage offer.[9] In period t, the incumbent firm chooses a job-assignment-wage-offer pair to maximise the total discounted profit given workers' types. If non-promotion is more profitable, the firm assigns the worker to the lower level job. Otherwise, the firm assigns the worker to the upper-level job. Due to the firm-specific human capital, an incumbent firm can potentially make positive profit by retaining an old worker.

When a firm makes decisions as an outside firm, i.e., when it considers wage bids for workers in other firms, its problem is characterised by a zero profit condition (due to free entry). Thus, the equilibrium wage in period t is equal to a worker's current period's productivity plus potential discounted future profits at an outside firm, $\Pi_{t+1}^{OUT}(\theta_i)$, i.e.,

$$w_{it}^j(\theta_i) = [\theta_i z_H^j + (1-\theta_i) z_L^j + f(t-1)] + \beta \Pi_{t+1}^{OUT}(\theta_i), j \in \{l, m\}, \theta_i \in \{\theta_g, \theta_r\}. \quad (5)$$

In the last period, since there are no future periods, a worker's wage is equal

[9]The expressions in 3 and 4 describe equilibrium behavior. The original firms' problem for this wage-bidding Bertrand competition is that the incubent firm and the outside firms choose their own wages holding other firms' wage bids as fixed. In equilibrium, those wages are equal. I omit the original expression to simplify the notation.

to her productivity in period T. In periods before T, a period-t "outside" firm would become an "incumbent" firm from period $t+1$ onward. This is because from period $t+1$ onward, a period-t outside firm starts to collect the firm-specific human capital as a period-t incumbent firm does. Since a period-t outside firm has the same information about a worker as a period-t incumbent firm does, the outside firm's expected future profit is equal to an incumbent firm's expected future profit from period $t+1$, i.e., $\Pi_{t+1}^{INC}(\theta_i) = \Pi_{t+1}^{OUT}(\theta_i) = \Pi_{t+1}(\theta_i)$. Thus, we can substitute (5) into (3) and (4), and an incumbent's job-assignment problem simplifies to

$$\Pi_t^{INC}(\theta_i) = S \cdot \{ \max_{l,m} [\theta_i z_H^l + (1-\theta_i) z_L^l, \theta_i z_H^m + (1-\theta_i) z_L^m] + f(t-1)\}, \theta_i \in \{\theta_g, \theta_r\}.$$

Since a good worker has higher expected productivity on the upper-level job and an ordinary worker has higher expected productivity on the lower level job, the good worker should be assigned to the upper-level job and the ordinary worker should be assigned to the lower level job in each period. Also, since workers of the same type are ex ante identical, the equilibrium wages are only functions of workers' types, i.e., all good workers are paid the same wage in a certain period while all ordinary workers are paid another. I thus omit the individual subscript in the wage equations in the rest of this section.

I summarise the job assignment rules and equilibrium wages under full information in the following proposition. All proofs are provided in the appendix.

Proposition 1. *Suppose each worker's type is fully observable. Then the job assignment rules and the equilibrium wages satisfy (i) and (ii):*

(i) A good worker is assigned to the management level in every period and is

paid $w_t^m(\theta_g) = [E_g^m + f(t-1)] + \beta S[E_g^m + f(t)]$ *in period* $1 \leq t < T$*; she is paid* $w_T^m(g) = E_g^m + f(T-1)$ *in period* T*;*

(ii) An ordinary worker is assigned to the labourer level in every period and is paid $w_t^l(\theta_r) = [E_r^l + f(t-1)] + \beta S[E_r^l + f(t)]$ *in period* $1 \leq t < T$*; she is paid* $w_{iT}^l(r) = E_r^l + f(T-1)$ *in period* T*.*

From Proposition 1, only the next period's productivity matters for the equilibrium wage. This is because the future profit is the extra economic rent that an incumbent firm can extract from collecting the benefit of one more period of firm-specific human capital compared to an outside firm. Thus, the rent is the next period's productivity multiplied by the firm-specific human capital factor S. This rent gives an outside firm an incentive to become an incumbent firm in the next period by bidding away a worker in the current period. Since firms are competing with each other over workers, all the economic rent is reflected in the equilibrium wage. The higher the firm-specific human capital is, the more a firm is willing to pay in anticipation of a higher rent from collecting the firm-specific part of the productivity.

Now let us consider how the timing of promotion is related to workers' wages. An ordinary worker's wage growth on the labourer job between two periods is $w_{t+1}^l(r) - w_t^l(r) = [f(t) - f(t-1)] + \beta S[f(t+1) - f(t)] > 0$. That is, a non-promoted worker's wage always increases with job tenure. A similar pattern is observed for good workers' wages. The reason is that under full information there is no learning with additional tenure, so workers' wages are determined solely by human capital accumulation which is non-decreasing with additional tenure. However, this prediction is inconsistent with the finding in Baker et al.(1994a) that non-promoted workers' wages first increase then decrease with tenure on the same job level for workers who spend a long time on the same job level. In the next section, I consider what happens when learning is asymmetric. I show that with asymmetric learning, non-promotion interacts with human capital accumulation and affects workers' wage dynamics through learning.

3.2 A Model with Asymmetric Information

With asymmetric information, incumbent firms observe outputs and update their beliefs about a worker being good and then make job assignment decisions and wage offers based on observed outputs. Outside firms observe workers' job assignments at the incumbent firms and update beliefs about workers' ability types. I focus on perfect Bayesian Equilibriums (PBE) of the model. That is, equilibrium beliefs are derived based on Bayes' rule given equilibrium strategies and equilibrium strategies are optimal for the incumbent firms, the outside firms, and the workers given the equilibrium beliefs.

Under the current framework, the incumbent firm never learns workers' true types. Furthermore, because of the binary output structure, when the incumbents make promotion announcements, they convey their private information about a worker's output in the current period completely under the parameterizations specified in the previous section. That is, whenever an incumbent firm observes the high-level productive efficiency, a worker is promoted; whenever an incumbent firm observes the low-level productive efficiency, a worker stays on the same job level (a promoted worker stays on the upper level job). In anticipating these equilibrium strategies, an outside firm believes that the high-level productive efficiency was attained at the labourer job when a promotion is observed; while a low-level productive efficiency was attained if a non-promotion is observed. It remains to check that under those beliefs the incumbents' strategies are indeed optimal.

The firms' problem is similar to the one under full information, i.e., incumbent firms choose a job-assignment-wage-offer pair to maximise total expected profit. The difference is that, since workers' types are unknown, workers' expected productivity is determined by the belief that a worker is good. Let $\Pi_t^{INC}(q_{it}^{INC})$ denote the incumbent firm's profit in period t from employing a worker who is believed (by the incumbent firm) to be good with probability q_{it}^{INC}. $\Pi_t^l(q_{it}^{INC})$ is the non-promotion profit and $\Pi_t^m(q_{it}^{INC})$ is the promotion profit from employing this worker. Then $\Pi_t^{INC}(q_{it}^{INC}) = \max\left\{\Pi_t^l(q_{it}^{INC}), \Pi_t^m(q_{it}^{INC})\right\}$, where

$$\Pi_t^l(q_{it}^{INC}) = (1+S)[q_{it}^{INC}E_g^l + (1-q_{it}^{INC})E_r^l + f(t-1)] - w_{it}^l + \beta\Pi_{t+1}^{INC}(q_{it}^{INC}, l), \tag{6}$$

$$\Pi_t^m(q_{it}^{INC}) = (1+S)[q_{it}^{INC}E_g^l + (1-q_{it}^{INC})E_r^l + f(t-1)] - w_{it}^m + \beta\Pi_{t+1}^{INC}(q_{it}^{INC}, m). \tag{7}$$

$\Pi_{t+1}^{INC}(q_{it}^{INC}, j), j \in \{l, m\}$, is the incumbent's future expected profit given the belief in t that a worker is good with probability q_{it}^{INC} and the fact that the worker is assigned to job j in period t.

The outside firms' problem is characterised by a zero profit condition, so an outside firm is willing to bid above a worker's current period's expected productivity because it can collect future rents when it becomes an incumbent firm. Similar to the property in the full information equilibrium, in determining wages, only the next period's job assignment and productivity are relevant to the expected rents because an incumbent firm only collects one more period of firm-specific human capital compared to an outside firm.

Outside firms' wage bids are

$$w_{it}^{l}(q_{it}^{OUT}) = [q_{it}^{OUT}E_{g}^{l} + (1-q_{it}^{OUT})E_{r}^{l} + f(t-1)] + \beta\Pi_{t+1}^{OUT}(q_{it}^{OUT}, l), \tag{8}$$

$$w_{it}^{m}(q_{it}^{OUT}) = [q_{it}^{OUT}E_{g}^{l} + (1-q_{it}^{OUT})E_{r}^{l} + f(t-1)] + \beta\Pi_{t+1}^{OUT}(q_{it}^{OUT}, m), \tag{9}$$

where q_{it}^{OUT} denotes the outside firm's belief in period t that worker i is good; $\Pi_{t+1}^{OUT}(q_{it}^{OUT}, j)$ denotes the outside firm's future expected profit given the belief in t that a worker is good and the fact that the worker is assigned to job j in period t.

Note that under asymmetric information, an outside firm's belief that a worker is good is based on the incumbents' job assignment signals while the incumbent's belief is based on workers' output realizations. That is, an incumbent firm and an outside firm have different information sets about each worker. Thus, the outside firm's belief about the worker and the expected future rents from this worker might be different from the incumbent firm's. However, parameter restriction (ii) guarantees that the incumbent firm promotes a worker when a high output is observed. Therefore, at the time of promotion, the incumbent and the outside firms have the same information about a non-promoted worker, i.e., $q_{it}^{INC} = q_{it}^{OUT} = q_{it}, \Pi_{t+1}^{INC}(q_{it}^{INC}, j) = \Pi_{t+1}^{OUT}(q_{it}^{OUT}, j) = \Pi_{t+1}(q_{it}, j)$. Thus, an incumbent's job-assignment problem simplifies to

$$
\begin{aligned}
\Pi_t[q_{it}(h_i^{t-1})] &= S \cdot \max_{l,m} \left\{ E[y_{it}^l | q_{it}(h_i^{t-1})], E[y_{it}^m | q_{it}(h_i^{t-1})] \right\} \\
&= S \cdot \max_{l,m} \left\{ q_{it}(h_i^{t-1}) E_g^l + [1 - q_{it}(h_i^{t-1})] E_r^l, q_{it}(h_i^{t-1}) E_g^m + [1 - q_{it}(h_i^{t-1})] E_r^m \right\} \\
&+ S \cdot f(t-1).
\end{aligned}
$$

Therefore, the equilibrium strategy is that if the belief of a worker being good is greater than the threshold, i.e., $q_{it} \geq q^*$ (recall that q^* equates the expected productivity on the two job levels), the worker is promoted. Otherwise, the worker remains in the previous job level. Given parameter restriction (i), once a high productive efficiency is observed (for the first time), the belief of this worker being good would be above the threshold and thus this worker will be promoted by an incumbent firm, i.e., since $q_{it}(1) > q_{iT}(1) > q^*$, once a worker attains the high productive efficiency, she is assigned to the manager position and remains there independent of subsequent output realizations.

At an outside firm, given the observed job assignment history, the expected future profit to an outside firm is the same whether the worker is assigned to the manager position or the labourer position in the current period. Thus, an outside firm only considers the current period's expected output when deciding where to assign a worker. If an outside firm observes a promotion (non-promotion), it believes that this worker has produced high (low) output at the incumbent firm and thus she is more productive on the upper (lower) level job in the current period. Therefore, a promoted (non-promoted) worker at an incumbent firm is also assigned to the upper-level (lower-level) job at an outside firm.

Let $E_t[Z_{it}^j|q_{it}(h_i^{t-1})]$ denote the part of the expected productivity in t that is determined by workers' ability types given the observed information up to $t-1$, i.e., $E_t[Z_{it}^j|q_{it}(h_i^{t-1})] = q_{it}(h_i^{t-1})E_g^j + [1-q_{it}(h_i^{t-1})]E_r^j$. Let $E_t[Z_{it+1}^j|q_{it}(h_i^{t-1}), j]$ denote the part of the expected productivity in $t+1$ from period t's perspective that is determined by workers' ability types given the observed information up to $t-1$ and the job assignment in t. The expression for $E_t[Z_{it+1}^{J_{it+1}}|q_{it}(h_i^{t-1}), j]$ is given in the appendix.

I summarise the job assignment rules and equilibrium wages under asymmetric information in the following proposition.

Proposition 2. *Suppose workers' types are not observed but the incumbent firms can observe workers' outputs and the outside firms can observe workers' job assignments. Given the prior belief that a worker is good with probability p_0, the job assignment rules and the equilibrium wages satisfy (i) to (iv):*

(i) All workers are assigned to the lower level job in period 1.

(ii) Let t_i be the first period in which worker i produces the high output. Then worker i is assigned to the labourer position in each period $t, t \leq t_i$. Her wage in t is $w_{it}^l[q_{it}(0)] = \{E_t[Z_{it}^l|q_{it}(0)] + f(t-1)\} + \beta S\{E_t[Z_{it+1}^{J_{it+1}}|q_{it}(0), l] + f(t)\}$.

(iii) Worker i is assigned to the manager position in each period $t, t_i + 1 \leq t < T$. Her wage in t is $w_{it}^m[q_{it_i+1}(1)] = \{E_t[Z_{it}^m|q_{it_i+1}(1)] + f(t-1)\} + \beta\{(1+S)E_t[Z_{it+1}^{J_{it+1}}|q_{it_i+1}(1), m] - E_t[Z_{it}^m|q_{it_i+1}(1)] + Sf(t)\}$.

(iv) In period T, if $t_i \leq T-1$, the worker is assigned to the manager job and is paid $w_{iT}^m[q_{it_i+1}(1)] = E[Z_{iT}^m|q_{it_i+1}(1)] + f(T-1)$; if $t_i > T-1$, she is assigned to

the labourer job and is paid $w^l_{iT}[q_iT(0)] = E[Z^l_{iT}|q_{iT}(0)] + f(T-1)$.

Note that for workers who have attained the high productive efficiency before period $T-1$, outside firms' beliefs about their types stop updating once they are promoted because outside firms cannot infer their outputs from job assignments anymore (see (*iv* in Proposition 2). However, outside firms expect a promoted worker to produce either high or low in the next period because there is no winner's curse and incumbents do not observe workers' types perfectly. After a worker worked for a firm for one period, the firm starts to collect new information about this worker. Thus, the expected rent derived from employing this worker is the difference between the worker's expected productivity at an incumbent firm in the next period, $(1+S)\{E_t[Z^{J_{it+1}}_{it+1}|q_{it_i+1}(1),m] + f(t)\}$, and the worker's expected productivity at an outside firm in the next period, $E_t[Z^m_{it}|q_{it_i+1}(1)] + f(t)$.

Now, let us consider how the non-promotion wages change with job-tenure. Note that all workers with the same output history are ex ante identical (i.e., $q_{it}(0) = q_{kt}(0), i \neq k$). That is, all the non-promoted workers in period t are paid the same wage. In the following discussion, I omit the subscript i for individuals. The wage paid to a worker who is on level l for t periods (i.e. she has attained the low-level productive efficiency in the previous $t-1$ periods) thus is $w^l_t[q_t(0)]$, and the wage paid to a worker who is on level l for $t+1$ periods (i.e. she has attained the low-level of productive efficiency in the previous t periods), is $w^l_{t+1}[q_{t+1}(0)]$.

Corollary 1. *Under asymmetric information, there exists a* t^*_1, $2 < t^*_1 \leq \bar{t}$, *such that if the following conditions are satisfied, the non-promoted workers' wages increase in periods before* t^*_1+1 *and decrease in periods after* t^*_1+1, *i.e., for* $t < t^*_1+1$,

$w_t^l[q_t(0)] < w_{t+1}^l[q_{t+1}(0)]$*; for* $t > t_1^* + 1$, $w_t^l[q_t(0)] > w_{t+1}^l[q_{t+1}(0)]$ *if*

$$f(t_1^*+1) - f(t_1^*) > [q_2(1) - q_3(1)][E_g^l - E_r^l], \text{ and} \tag{10}$$

$$f(t_1^*+2) - f(t_1^*+1) < [q_{\bar{t}}(1) - q_{\bar{t}+1}(1)][E_g^l - E_r^l].^{10} \tag{11}$$

Corollary 1 says that when human capital accumulation exceeds the negative learning about workers' ability with additional tenure, wages increase; when human capital grows little between two periods, the negative learning about workers' abilities lead to a wage decrease.

To see how the conditions in (10) and (11) guarantee the wage patterns described in Corollary 1, note that as additional low outputs are observed, the expectation that a worker is good decreases, i.e., $q_t(0) > q_{t+1}(0)$, for $t \geq 2$. Since $E_g^l > E_r^l$, the part of the wage that is related to workers' ability types, $E_t[Z_t^l | q_t(0)] = q_t(0)E_g^l + [1 - q_t(0)]E_r^l$, decreases when firms put a smaller weight on the belief that a worker is good. Similarly, the forward expectation, $E_t[Z_{t+1}^{J_{t+1}} | q_t(0), l]$, also decreases in t, because it is less likely that a worker would produce high in the next period if she has produced more low outputs in the past. Since both expectations are bounded, if there is substantial human capital accumulation from period t to period $t+1$, the non-promotion wage increases. If the human capital accumulation from period t to period $t+1$ is sufficiently small, the non-promotion wage decreases. By construction, since human capital accumulates very fast when t approaches 1 and it almost stops growing after $\bar{t}$, there exists at least one period between period 2 (note that tenure in period 2 is equal to 1) and period $\bar{t}+1$ such that the non-promotion wage turns from increasing to decreasing.

Furthermore, the expectation about workers' types decreases at a decreasing speed and eventually approaches zero when t approaches ∞. Thus, the largest decrease in expectation is between period 2 and 3. On the other hand, human capital increases at a decreasing speed and eventually approaches zero when t approaches $\bar{t} < \infty$. Thus, the largest increase in human capital after period $t_1^* + 1$ is $f(t_1^* + 2) - f(t_1^* + 1)$. The condition in (10) guarantees that in periods before $t_1^* + 1$ the smallest human capital accumulation outweighs the largest expectation decrease. Thus, workers' wages increase before period $t_1^* + 1$. After that, the condition in (11) guarantees that the largest human capital accumulation is smaller than the smallest expectation decrease. Therefore, workers' wages decrease after period $t_1^* + 1$.[11]

As graphed in Baker et al. (1994a), for workers who are promoted from level 1 to level 2 within six years of tenure on level 1, their (real) wages prior to the promotion increase with each additional year of job-level tenure. For workers who are promoted after the sixth year, their wages prior to the promotion first increase then decrease with additional level-1 tenure. This empirical finding departs from Bernhardt's (1995) prediction that the non-promotion wages either increase or decrease monotonically with firm-level tenure but is captured in the above Corollary.

Using a similar argument, one can examine the wage-tenure relation for wages upon promotion.

Corollary 2. *Under asymmetric information, there exists a t_2^*, $3 < t_2^* \leq \bar{t}$, such that if the following conditions are satisfied, the promotion wages increase in periods*

[11] If the conditions in (10) and (11) are not satisfied, I still get the result that non-promoted workers' wages increase when tenure is low and their wages eventually fall (after $\bar{t} + 1$ for example). But I cannot guarantee that the non-promotion wages only turn once from increasing to decreasing.

before t_2^*+1 *and decrease in periods after* t_2^*+1*, i.e., for* $3 \leq t < t_2^*+1$*,* $w_t^m[q_t(1)] < w_{t+1}^m[q_{t+1}(1)]$*; for* $t > t_2^*+1$*,* $w_t^m[q_t(1)] > w_{t+1}^m[q_{t+1}(1)]$ *if*

$$f(t_2^*+1) - f(t_2^*) > \frac{1+S}{S}[q_4(2) - q_5(2)][E_g^l - E_r^l], \text{ and} \tag{12}$$

$$f(t_2^*+2) - f(t_2^*+1) < (1-\beta)[q_{\bar{t}}(2) - q_{\bar{t}+1}(2)][E_g^l - E_r^l]. \tag{13}$$

Similar to the non-promotion wage, the wage in the period of promotion first increases then decreases with more time spent on the lower level job before promotion. Baker et al. (1994a) find that if a worker earns a promotion within four years on level 1, the wage that she earns upon promotion is higher than the wage paid to someone who is promoted in the previous period. On the other hand, if a worker earns a promotion after spending more than four years on level 1, the wage that she earns upon promotion is lower than the wage paid to someone who is promoted in the previous period.

Note that the condition in (12) is stronger than that in (10) since $q_t(2) - q_{t+1}(2) > q_t(1) - q_{t+1}(2) > q_t(0) - q_{t+1}(0)$. Therefore, it is possible that $t_2^* < t_1^*$, which means the promotion wage falls before the non-promotion wage does.

It is worth noticing that the signaling effect is embedded in job-tenure rather than firm-tenure. In the current set up, the level-l job-tenure is equal to firm-tenure before promotion. Suppose I were to extend the model to include a level below the labourer's level, call it the routine level, where workers' productivities do not vary with abilities and workers in this level are randomly selected into the labourer's level. If we compare a worker who has eleven years of firm tenure with four years on the routine job and seven years on the labourer's job to a worker who has ten years of firm-tenure with two years on the routine job and eight years on the labourer's job, if both workers are not promoted in the current period, the former would earn a higher wage than the latter although she has longer firm-tenure. The latter has a lower wage because she spends more time on the labourer's position. That is, the negative signal is associated with job-tenure rather than firm-tenure.

4 Data and Tests

In Baker et al. (1994a), the wage-job-tenure profile is shown using a raw plot. In this section, I use the same dataset that they have studied to estimate a tenure-wage equation controlling for other observables. I focus on the relationship between job-tenure and non-promotion wages as well as the relationship between job-tenure (before promotion) and promotion wages.

The dataset was constructed by George Baker, Michael Gibbs, and Bengt Holmstrom from the personnel records of a medium-sized US firm in the financial services industry. It contains detailed information on workers' demographic characteristics, tenure, subjective performance evaluation, and promotion history. In their seminal papers, Baker et al. (1994a;b) provide a thorough analysis of wage and career dynamics in this firm during a 20-year period from 1969 to 1988 using the full sample of managerial employees for a total of 68,437 employee-year data points. In this analysis, I restrict the sample to US white males to focus on the wage dynamics without concerning the gender-wage-gap. I also exclude demotion, which takes up 2%-3% of the sample. Since I use a one-year lag in calculating job-tenure, I exclude the entry cohort '69. I also exclude any data points with missing per-

Table 1: Levels, Titles, and Education

Level	TITLE	HS	BS	MA	PHD	Total
1	AH	80	78	16	7	181
N=4,699		44.2	43.09	8.84	3.87	100
Pct.=29.63%	AJ	1,460	1,301	481	31	3,273
		44.61	39.75	14.7	0.95	100
	AK	766	402	77	0	1,245
		61.53	32.29	6.18	0	100
2	H	59	73	20	17	169
N=5,399		34.91	43.2	11.83	10.06	100
Pct.=34.05%	I	43	124	21	0	188
		22.87	65.96	11.17	0	100
	J	97	134	70	17	318
		30.5	42.14	22.01	5.35	100
	K	428	180	59	0	667
		64.17	26.99	8.85	0	100
	L	1,406	585	209	3	2,203
		63.82	26.55	9.49	0.14	100
	M	551	848	409	46	1,854
		29.72	45.74	22.06	2.48	100
3	F	21	80	22	0	123
N=5,759		17.07	65.04	17.89	0	100
Pct.=36.32%	G	2,327	1,905	1,056	105	5,393
		43.15	35.32	19.58	1.95	100
	SH	47	148	24	24	243
		19.34	60.91	9.88	9.88	100
	Total	7,285	5,858	2,464	250	15,857
		45.94	36.94	15.54	1.58	100

formance measure and I exclude years of schooling 15,17,19, and 20 since those years of schooling are hard to categorise with a degree measure. There are eight job levels, where level 8 is the CEO position.[12] I only look at workers on levels 1 to 3 since the promotion and wage dynamics on upper-level jobs might be very different from those on lower level jobs. Moreover, I want to focus my analysis on the same sample that generates the wage plots in Baker et al. (1994a). In those plots, they focus on the wage and job-tenure relations on level 1 through level 3. This sample selection procedure gives me a sample of 15,857 employee-year data points across three job levels.

Table 1 presents the 17 major job titles as specified in Baker et al. (1994a;b), grouped by job levels and interacted with education groups following DeVaro and Waldman (2012). Observations are roughly equally distributed across three job levels, with 30% from level 1, 34% from level 2, and 36% from level 3. There are 12 job titles on level 1 to 3 but there are one or two job titles that are the dominant job title on a particular level.

Table 2 presents the descriptive statistics. Supervisor subjective performance ratings are measured annually on a five-point scale where 1 denotes the best performance and 5 the worst. There are roughly equal numbers of employee-years in the three job levels. The average tenure at the firm is 3.7 years and the average tenure in the job level is 2.6 years. Workers on average spend 2.3 years on level 1 before being promoted to level 2. They spend a little longer, 2.6 years, on level 2 before being promoted to level 3. Around 15% of the employees are promoted in each sample year.

[12] See Baker et al. (1994a;b) for detail descriptions about how the job levels are constructed.

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Salary (in 1988 dollar)	15857	46726.37	10483.57	20846.91	109890.10
ΔReal Salary	11859	1644.12	3047.10	-13522.83	30163.46
Δ% Real Salary	11859	0.04	0.07	-0.24	0.91
Age	15857	39.03	9.43	23.00	69.00
High School	15857	0.46	0.50	0.00	1.00
Bachelor	15857	0.37	0.48	0.00	1.00
Master	15857	0.16	0.36	0.00	1.00
PhD	15857	0.02	0.12	0.00	1.00
Performance Rating (t-1)	11859	1.95	0.71	1.00	5.00
Year at Company (t-1)	13372	3.74	3.51	0.00	18.00
Year at Level (t-1)	15086	2.60	2.56	0.00	17.00
Promotion	15857	0.15	0.36	0.00	1.00

To test the job-tenure-wage profile, I consider the following wage equation.

$$w_{it} = \beta_0 + \beta_1 L_{it-1} + \beta_2 W_{i0} + \beta_3 X_{it-1} + \varepsilon_{it} \tag{14}$$

i indexes an individual and t indexes years. X_{it-1} is a vector of controls including age and age squared, education, and performance rating in the previous year. L_{it-1} is year at level in $t-1$ before promotion. Thus, it denotes the job-level tenure at the previous level for a just promoted worker and job-level tenure at the current level up to $t-1$ for a non-promoted worker. W_{i0} is worker i's first salary at the firm, which is a control for workers' initial characteristics (Belzil et al., 2012). Workers' initial characteristics need to be controlled for because the model predictions concern learning about ex ante identical workers. Since the initial wage carries rich information about an individual, I use it as a proxy for workers' initial heterogeneity.

The sample that I use to test the non-promotion-wage-job-tenure relation is re-

Table 3: Wage-tenure profile before promotion (quadratic): level=1

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE
		Dependent Variable: Real Salary in 88 Dollars			
Yr. at Level	80.128	1,120.291**	771.463**	1,256.270**	1,002.114**
(t-1)	(53.370)	(111.222)	(124.559)	(214.247)	(127.373)
Yr at Level^2		-135.559**	-99.508**	-112.916**	-79.256**
(t-1)		(12.083)	(12.466)	(17.230)	(10.237)
Entry Salary	0.328**	0.328**	0.313**	0.353**	
	(0.014)	(0.014)	(0.014)	(0.024)	
Rating (t-1)				-2,333.563**	
				(244.979)	
Age (t-1)			1,170.840**	889.369**	1,905.166**
			(87.675)	(137.627)	(254.780)
Age^2(t-1)			-14.225**	-11.218**	-24.356**
			(1.071)	(1.593)	(2.885)
High School			-307.858	-827.032*	
			(250.931)	(354.364)	
Master			3,649.813**	2,721.757**	
			(349.193)	(612.507)	
PhD			2,863.510**	1,972.203	
			(890.531)	(1,145.488)	
Constant	31,559.206**	30,848.928**	8,778.494**	18,337.007**	3,235.066
	(341.818)	(346.468)	(1,642.439)	(2,709.431)	(5,608.402)
Observations	4,516	4,516	4,516	2,338	4,518
R-squared	0.147	0.166	0.223	0.237	0.954

Robust standard errors in parentheses
** $p<0.01$, * $p<0.05$

stricted to those individuals who are on the same job level in a particular year and I consider individuals on different job levels separately. The sample that I use to test the promotion-wage-job-tenure relation is restricted to those individuals who are just promoted in a particular year and I consider the individuals who are promoted from level 1 to level 2 and those who are promoted from level 2 to level 3 separately.

Table 3 looks at the relationship between job-tenure and non-promotion wages (in real terms) for those individuals on level 1. The table begins with the most parsimonious specification with only job-tenure in the previous period and the entry salary as the explanatory variables in Column (1). There is a positive relationship between wage and job-tenure but it is not statistically significant. Each column from (2) to (4) adds additional controls. Column (2) adds a quadratic term for job-tenure. Column (3) includes controls for age and education. Column (4) adds controls for performance rating. The hump-shaped wage-job-tenure relation remains after I control for performance rating. However, in the theoretical model workers' wages are not conditioned on their output, which can be reflected in the performance measure, so column (3) is a better test of the theory without controlling for the performance rating.[13] In Column (5), I consider a fixed-effect model on individual level excluding performance ratings. The relationship between job-tenure and the non-promoted workers' wage persists regardless of model specifications. In particular, the non-promoted workers' wage first increases then starts to fall. These results match Baker et al.'s (1994a) wage plots very well.

Note that, the OLS models compare the average wages across individuals and

[13] See DeVaro and Waldman (2012) for a discussion of using performance rating as a measure of output.

the fixed-effect model captures within person wage dynamics. From the theoretical model, all the non-promoted workers in a given period are paid the same wage because they are identical in all other dimensions. In practice, workers differ in age, education, performances and other dimensions. Therefore, I control for other observables in the OLS models. However, there might still be other unobserved individual characteristics that are driving the results. So the estimates of the OLS models capture two effects. First, those individuals who stay on level 1 for a shorter period of time on average earn a higher wage than those who stay longer because the former are more able to earn a promotion earlier. Second, each individual has a smaller wage increase (and eventually wage decrease) with longer tenure on the same level. The theoretical model suggests that we should also observe the hump-shaped wage-tenure pattern when we compare within individuals and these predictions are supported by the estimates from the fixed-effect model.[14]

Table 4 examines the job-tenure-non-promotion-wage relation using job-tenure dummies instead of imposing the quadratic form on job-tenure in the wage equation. We can see that the non-promoted workers' wages increase with job-tenure then start to fall after four or five years. For example, from Column (1), with three year tenure on job 1, a worker's wage is $1,969 higher than the entry wage; with four year tenure on job 1, a worker's wage is only $1,544 higher than the entry wage, which means the worker's wage starts to fall in the fourth year. If a worker spends more than six years on level 1 without a promotion, her wage even falls be-

[14]There is a discrepancy between the theory and the empirical specification in (14) that in the theory workers only differ in their time-to-promotion. That is, all workers with the same job assignment history are paid the same wage. As discussed in Gibbons and Waldman (1999a), one way to enrich the model is to include different observed education levels such that workers with the same job assignment history are paid differently.

Table 4: Wage-tenure profile before promotion (year dummies): level=1

	(1) OLS	(2) OLS	(3) OLS	(4) FE
Yr at Level(t-1)	*Dependent Variable: Real Salary in 88 Dollars*			
1	1,327.494**	850.815**	-677.111	1,193.591**
	(289.458)	(286.645)	(353.374)	(141.784)
2	1,603.746**	784.368*	407.647	2,138.382**
	(357.945)	(377.822)	(344.477)	(223.858)
3	1,969.184**	1,010.640*	800.016	2,845.665**
	(470.574)	(500.490)	(457.721)	(328.424)
4	1,544.368**	530.355	526.257	3,057.691**
	(544.806)	(569.671)	(535.426)	(388.907)
5	716.288	-267.627	188.531	3,398.000**
	(643.595)	(660.488)	(626.804)	(494.805)
6	-325.991	-1,109.076	-127.689	3,224.353**
	(780.660)	(813.315)	(753.214)	(601.316)
7	-944.832	-1,641.365	-850.610	3,142.963**
	(989.624)	(977.187)	(922.020)	(755.284)
8	-4,072.561**	-4,371.377**	-3,399.209**	2,132.144*
	(1,096.801)	(1,089.629)	(1,072.734)	(877.605)
9	-4,696.114**	-5,248.299**	-4,232.494**	2,884.836**
	(1,485.813)	(1,480.712)	(1,419.875)	(1,084.924)
10	-6,822.486**	-6,992.827**	-5,512.765**	3,278.206*
	(1,876.262)	(1,573.646)	(1,565.759)	(1,424.512)
11	-4,745.591	-5,859.753*	-4,843.347	2,259.449
	(3,485.411)	(2,812.724)	(2,894.402)	(1,975.629)
12	-6,727.453**	-6,466.210**	-5,047.442**	1,521.800
	(807.280)	(1,284.532)	(1,300.991)	(1,391.815)
13	-7,321.807**	-6,495.907**	-5,126.091**	1,897.945
	(913.263)	(1,207.943)	(1,206.696)	(1,656.205)
Entry Salary	0.327**	0.313**	0.354**	*No*
	(0.014)	(0.014)	(0.024)	*No*
Age	*No*	*Yes*	*Yes*	*Yes*
Education	*No*	*Yes*	*Yes*	*No*
Rating	*No*	*No*	*Yes*	*No*
Constant	38,402.605**	13,989.254**	24,168.928**	7,151.725
	(175.917)	(1,729.504)	(3,103.598)	(5,009.659)
Observations	4,518	4,518	2,338	4,518
R-squared	0.026	0.097	0.107	0.954

Robust standard errors in parentheses
** $p<0.01$, * $p<0.05$

low the entry level. These patterns remain after I control for age and education in Column (2). In Column (3), I add controls for performance rating. The wage pattern remains. Column (4) presents the fixed-effect estimates with job-tenure dummies. We can see that workers wages increase fast in the first five years on the job and starts to fall in the sixth year.

Table 5: Wage-tenure profile before promotion(quadratic): level=2

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE
			Dependent Variable: Real Salary in 88 Dollars		
Yr. at Level	-20.267	1,084.606**	733.951**	913.175**	454.667**
(t-1)	(34.432)	(128.834)	(146.204)	(166.053)	(88.055)
Yr at Level^2		-88.054**	-59.899**	-46.615**	-50.066**
(t-1)		(9.830)	(10.967)	(13.778)	(6.686)
Entry Salary	0.308**	0.338**	0.317**	0.373**	
	(0.013)	(0.013)	(0.013)	(0.016)	
Rating (t-1)				-2,361.349**	
				(181.537)	
Age (t-1)			1,179.609**	1,117.072**	2,388.337**
			(91.296)	(101.540)	(220.122)
Age^2(t-1)			-13.988**	-13.186**	-25.694**
			(1.078)	(1.179)	(2.488)
High School			-801.273**	-791.539**	
			(265.289)	(283.761)	
Master			3,055.688**	2,475.624**	
			(342.154)	(378.475)	
PhD			1,960.592*	1,313.417	
			(944.297)	(1,115.009)	
Constant	37,490.788**	35,143.455**	12,620.226**	16,757.512**	-7,025.540
	(317.198)	(425.766)	(1,764.041)	(1,980.936)	(4,636.120)
Observations	4,574	4,574	4,574	3,779	5,141
R-squared	0.111	0.127	0.174	0.199	0.930

Robust standard errors in parentheses
** p<0.01, * p<0.05

Table 5 and Table 6 repeat the analyses in Table 3 and Table 4 for workers who

Table 6: Wage-tenure profile before promotion(year dummies): level=2

	(1) OLS	(2) OLS	(3) OLS	(4) FE
Yr at Level(t-1)	*Dependent Variable: Real Salary in 88 Dollars*			
1	3,642.644**	2,721.035**	-	2,237.414**
	(596.568)	(544.034)	-	(335.115)
2	4,056.761**	2,868.391**	778.697*	2,414.836**
	(620.571)	(586.657)	(330.145)	(364.138)
3	4,151.822**	2,798.967**	1,098.994**	2,829.843**
	(656.452)	(633.962)	(395.853)	(378.361)
4	4,976.847**	3,474.826**	2,227.494**	2,888.903**
	(706.598)	(692.060)	(484.368)	(409.393)
5	5,318.720**	3,808.978**	2,861.933**	2,760.834**
	(764.215)	(759.700)	(573.743)	(439.888)
6	5,472.409**	3,956.963**	2,869.221**	2,241.372**
	(873.991)	(861.200)	(681.666)	(496.213)
7	6,864.477**	5,570.411**	4,544.755**	2,363.988**
	(1,089.764)	(1,059.840)	(909.445)	(622.746)
8	4,548.405**	3,488.197**	2,876.764**	1,170.001
	(1,075.865)	(1,043.605)	(913.311)	(667.476)
9	4,452.337**	3,531.212**	2,737.820**	-37.641
	(1,073.098)	(1,079.420)	(913.661)	(729.459)
10	2,998.101**	2,133.263	1,864.390	-1,141.041
	(1,162.290)	(1,244.446)	(1,069.091)	(815.523)
11	4,278.598**	3,146.789*	2,939.162*	-797.063
	(1,457.885)	(1,494.909)	(1,360.042)	(917.085)
12	5,437.926**	4,927.277*	4,471.845*	-815.763
	(2,057.511)	(2,145.260)	(2,036.756)	(1,153.356)
13	1,343.494	876.404	4,195.668**	-488.140
	(711.369)	(657.982)	(1,034.647)	(454.285)
Entry Salary	0.345**	0.324**	0.373**	*No*
	(0.013)	(0.013)	(0.016)	*No*
Age	*No*	*Yes*	*Yes*	*Yes*
Education	*No*	*Yes*	*Yes*	*No*
Rating	*No*	*No*	*Yes*	*No*
Constant	42,978.276**	17,113.012**	22,109.807**	-7,541.936
	(570.767)	(1,696.482)	(1,956.427)	(4,714.525)
Observations	5,141	5,141	4,235	5,141
R-squared	0.011	0.069	0.079	0.932

Robust standard errors in parentheses
** p<0.01, * p<0.05

stay on level 2. The hump-shape wage-tenure profile is still evident in both specifications with either a quadratic term on year-at-level or job-tenure dummies. Column (4) in each table controls for age, education and performance rating. Column (5) considers a fixed-effect model. From the fixed-effect model, the non-promotion wage on level 2 starts to fall in year 5.

Note that I do not control for firm tenure for the non-promoted workers for two reasons. First, for individuals who are on level 1, their firm tenure is equal to their job tenure. Second, for a non-promoted worker on level 2, conditional on firm tenure, those who have longer level-2 tenure in general should have shorter level-1 tenure. If more able workers are promoted earlier on level 1, those individuals who have longer level-2 tenure should earn a higher wage. On the other hand, long tenure on level 2 sends a negative signal. So, holding firm tenure fixed, the theory predicts that wages can either increase or decrease with job tenure on level 2. The current specification without controlling for firm tenure examines the average effect of level-2 tenure on wages allowing individuals to have different years of tenure on level 1.

Table 7 examines the average wages in the year of promotion for workers with different job-tenure on the lower level job before promotion. Columns (1) and (2) consider the promotion wage when a worker is promoted from level 1 to level 2. From Column (1), the promotion wage first increases then decreases with tenure on the job before promotion but the estimates are not statistically significant. From Column (2), the promotion wage increases when tenure on the previous job is low and decreases with tenure on the previous job is high but the relationship flips signs several times. From Corollary 2, the promotion wage may change signs multiple times if the conditions in (13) and (13) are not satisfied. Thus, these wage patterns are not inconsistent with the model.

Columns (3) and (4) in Table 7 look at the promotion wage when a worker is promoted from level 2 to level 3. Overall, if a worker spends less time on level 2 before she is promoted, she earns a higher wage upon promotion. We do not observe the promotion wage increase when the job-tenure on level 2 is low. As I discussed in the theoretical analysis, under certain parameterization, it is possible that the promotion wage falls when the non-promotion wage is still increasing because the promotion wage is more sensitive to learning.

In summary, the empirical evidence supports the model's prediction about the non-promoted workers' wages and job-tenure. Job-tenure not only affects workers' human capital levels but also carries rich information about workers' unobserved ability. As discussed in Gibbs (1995), job tenure can be used as a proxy for workers' unobserved ability.

5 Conclusion

This article develops a theoretical framework to explore the negative signals associated with non-promotion. It contributes to the literature in three different ways. First, it fills a gap in the learning literature by capturing the negative signaling role of non-promotion. Second, this article emphasises the relationship between wages and job-level tenure instead of firm-level tenure. Third, it provides a systematic explanation for a set of empirical findings that are not well captured in existing models. My model shows that non-promoted workers' wages decrease when they

Table 7: Promotion Wage and Job Tenure Before Promotion

	level 1 to level 2		level 2 to level 3	
	(1)	(2)	(3)	(4)
	Dependent Variable: Real Salary in 88 Dollars			
Year at Level (t-1)	339.530		-380.067	
	(448.027)		(465.726)	
Year at Level Sq. (t-1)	-21.349		27.759	
	(55.417)		(46.083)	
Year at Level (t-1)				
2		-143.129		-856.522
		(509.929)		(647.654)
3		-162.140		39.202
		(656.884)		(869.102)
4		1,252.088		-1,354.274
		(898.077)		(1,098.808)
5		814.904		606.428
		(1,310.348)		(1,646.929)
6		2,086.035		-1,271.724
		(1,401.184)		(1,590.442)
7		92.246		-4,181.807*
		(2,003.750)		(1,834.913)
8		1,140.458		5,537.766
		(1,817.991)		(3,156.209)
9		-2,937.925**		-4,234.630**
		(1,030.795)		(1,420.881)
10		2,671.382		-3,086.256*
		(5,183.328)		(1,243.448)
11		-7,249.871**		-
		(661.319)		-
12		-		5,727.921**
		-		(1,374.278)
Entry Salary	0.335**	0.336**	0.315**	0.312**
	(0.026)	(0.026)	(0.030)	(0.031)
Age	*Yes*	*Yes*	*Yes*	*Yes*
Education	*Yes*	*Yes*	*Yes*	*Yes*
Constant	17,521.364**	17,164.737**	26,881.535**	26,979.739**
	(3,334.137)	(3,448.835)	(4,731.407)	(4,881.879)
Observations	1,170	1,170	910	910
R-squared	0.173	0.178	0.168	0.181

Robust standard errors in parentheses
** p<0.01, * p<0.05

spend a long time on the same job level, while their wages increase in the early years on the job. The empirical tests show clear evidence for a hump-shaped wage-job-tenure profile for the non-promoted workers. These results suggest that, besides determining workers' levels of human capital, job tenure carries additional information about individuals' unobserved ability. The trade-off between negative learning and positive human capital accumulation associated with additional tenure shapes the wage-job-tenure profile.

There are a number of ways to extend the model. First, there is no turnover in this model except for the exogenous movers. If workers are fully aware of the negative signals associated with non-promotion, they may choose change their jobs (or firms) before the negative signals about their abilities are revealed through non-promotion. Second, I can allow for heterogeneity in the initial human capital stock by incorporating education. The strength of the negative signals is expected to be different for workers with different initial levels of human capital.

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7 Mathematical Appendix

Expression for Parameterisation (ii)

$$(1+S)\{E[y^m_{iT}|q_{iT}(1)] - E[y^l_{iT}|q_{iT}(1)]\} > E[y^m_{iT}|q_{iT}(1)] - E[y^l_{iT}|q_{iT}(0)].$$

This condition guarantees that a worker is promoted when a high productive efficiency is attained because the productivity gain from correct job assignment is larger than the loss in terms of paying a higher wage by sending the promotion signal to the market.

Proof of Proposition 1. In period T, the incumbent's and the outside firm's problem is to maximise the expected productivity in period T. Thus, a good worker is assigned to the upper-level job. In period T-1, in anticipating that a good worker is assigned to the upper-level job, the incumbent and the outside firms also maximise the expected productivity in period T-1 and assign a good worker to the upper-level job. By induction, a good worker is always assigned to the upper-level job. $\|$

Proof of Proposition 2. Since the incumbent's assignment decision is made by maximizing the current period productivity, given parameter restriction (i), all young workers are assigned to the lower level job. Now, observe that $q_t(0) < q_{t-1}(0) < \ldots < q_2(0)$, given parameter restriction (ii), if a worker continues to produce low, the expectation that she is good is below q^*. Therefore, a worker who produce low remains on level-l. Also, since the belief that a worker is good only depends on the total number of high productive efficiency that has been achieved up to a certain period, in period T, no matter when a worker attains a high output, the belief that she is good is the same. In addition, a worker with only one high output up to $T-1$ is less likely to be a good worker compared to workers with more high outputs. Thus, if a worker with only one high output in the previous $T-1$ periods is more productive on the upper level in expectation, all other types should be more productive on the upper level. Therefore, $q^* < q_T(1) < q_T(2) < \ldots < q_T(T-1)$ guarantees that once a worker attains high output, she is always more productive on the upper-level job. Parameter restriction (iii) guarantees that an incumbent firm gain more through correct job assignment and to assign a worker with at least one high output in the previous $T-1$ periods to the upper level job. $\|$

Proof of Corollary 1. From Proposition 2,

$$\begin{aligned} w_t^l[q_t(0)] &= \{q_t(0)E_g^l + [1-q_t(0)]E_r^l + f(t-1)\} \\ &+ \beta S\{[q_t(0)\theta_g + (1-q_t(0))\theta_r][q_{t+1}(1)E_g^m + (1-q_{t+1}(1))E_r^m] \\ &+ [q_t(0)(1-\theta_g) + (1-q_t(0))(1-\theta_r)][q_{t+1}(0)E_g^l + (1-q_{t+1}(0))E_r^l] + f(t)\} \end{aligned}$$

So $w_t^l[q_t(0)] - w_{t+1}^l[q_{t+1}(0)]$

$$\begin{aligned} &= [q_t(0) - q_{t+1}(0)][E_g^l - E_r^l] - [f(t) - f(t-1)] \\ &+ \beta S\{E_t[Z_{t+1}^{J_{t+1}}|q_t(0), l] - E_{t+1}[Z_{t+2}^{J_{t+2}}|q_{t+1}(0), l] - [f(t+1) - f(t)]\}. \end{aligned}$$

From Bayes' Rule, $q_t(0) = \frac{p_0(1-\theta_g)^{t-1}}{p_0(1-\theta_g)^{t-1} + (1-p_0)(1-\theta_r)^{t-1}}$. Thus,

$$\Delta q_t(0) = q_t(0) - q_{t+1}(0) = \frac{1}{1 + \frac{1-p_0}{p_0}\left(\frac{1-\theta_r}{1-\theta_g}\right)^{t-1}} - \frac{1}{1 + \frac{1-p_0}{p_0}\left(\frac{1-\theta_r}{1-\theta_g}\right)^{t}},$$

which decreases in t. Therefore, $q_2(0) - q_3(0) > q_t(0) - q_{t+1}(0)$. Similarly $q_t(1) - q_{t-1}(1) > q_{t+1}(1) - q_t(1), q_{t+1}(1) - q_t(1) > q_{t+1}(0) - q_t(0)$. Since $f(t) - f(t-1) > f(t_1^*) - f(t_1^* - 1) > f(t_1^* + 1) - f(t_1^*) > [q_2(1) - q_3(1)][E_g^l - E_r^l] > [q_t(1) - q_{t+1}(1)][E_g^l - E_r^l] > [q_t(0) - q_{t+1}(0)][E_g^l - E_r^l]$ for $t < t_1^* + 1$, $w_t^l < w_{t+1}^l$. Since $f(t+1) - f(t) < f(t_1^* + 2) - f(t_1^* + 1) < [q_{\bar{t}}(1) - q_{\bar{t}+1}(1)][E_g^l - E_r^l] < [q_t(1) - q_{t+1}(1)][E_g^l - E_r^l]$ for $t_1^* + 1 < t \leq \bar{t}$ and $f(t+1) - f(t) \to 0$ for $t \geq \bar{t}$, $w_t^l > w_{t+1}^l$. ‖

Proof of Corollary 2. For a promoted worker who attains H in t, in expectation, this worker can produce H or L in the next time but her expected productivity is fixed at the time t when she attains H. Thus,

$$\begin{aligned} w_t^m[q_t(1)] &= \{q_t(1)E_g^m + [1-q_t(1)]E_r^m + f(t-1)\} \\ &+ \beta\{(1+S)[q_t(1)\theta_g + (1-q_t(1))\theta_r][q_{t+1}(2)E_g^m + (1-q_{t+1}(2))E_r^m] \\ &+ (1+S)[q_t(1)(1-\theta_g) + (1-q_t(1))(1-\theta_r)][q_{t+1}(1)E_g^m + (1-q_{t+1}(1))E_r^m] \\ &- \{q_t(1)E_g^m + [1-q_t(1)]E_r^m\} + Sf(t)\} \end{aligned}$$

So $w_t^m[q_t(1)] - w_{t+1}^m[q_{t+1}(1)]$

$$\begin{aligned} &= (1-\beta)[q_t(1) - q_{t+1}(1)][E_g^m - E_r^m] - [f(t) - f(t-1)] \\ &+ \beta\{(1+S)\left[E_t[Z_{t+1}^{J_{t+1}}|q_t(1), m] - E_{t+1}[Z_{t+2}^{J_{t+2}}|q_{t+1}(1), m]\right] - S[f(t+1) - f(t)]\}. \end{aligned}$$

Similar to the proof for Corollary 1, $\Delta q_{t+1}(2) > \Delta q_{t+2}(2)$ for $t \geq 3$. Using similar argument, since $f(t) - f(t-1) > f(t_2^*) - f(f_2^* - 1) > f(t_2^* + 1) - f(f_2^*) >$

$\frac{1+S}{S}[q_4(2)-q_5(2)][E_g^l-E_r^l] > \frac{1+S}{S}[q_t(2)-q_{t+1}(2)][E_g^l-E_r^l] > (1-\beta)[q_t(1)-q_{t+1}(1)][E_g^m - E_r^m]$ for $3 \leq t < t_2^*+1$, $w_{t+1}^m[q_{t+1}(1)] > w_t^m[q_t(1)]$; since $f(t+1)-f(t) < f(t_2^*+2)-f(t_2^*+1) < (1-\beta)[q_{\bar{t}}(2)-q_{\bar{t}+1}(2)][E_g^l-E_r^l] < \frac{1+S}{S}[q_{\bar{t}}(2)-q_{\bar{t}+1}(2)][E_g^l-E_r^l]$ for $t > t_2^*+1$ and $f(t+1)-f(t) \to 0$ for $t \geq \bar{t}$, $w_{t+1}^m[q_{t+1}(1)] < w_t^m[q_t(1)]$. ‖