On-the-Job Specific Training and Efficient Screening

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Employment relationships are governed by short-term incomplete contracts and typically involve on-the-job screening and firm-specific training. This article studies a dynamic employment relationship with these features and identifies a potential conflict between the employer's twin objectives to screen and train the worker: when the training technology is quite productive, the employer may have to sacrifice from worker performance during the screening process. The article thus offers an explanation for why firms may invest suboptimally on training, which complements the standard "inappropriable rents" explanation based on ex post mobility of young employees.

I. Introduction

Employment relationships have three important aspects. First, they are typically governed by short-term incomplete contracts due to prohibitive costs of defining and verifying "worker performance." Second, there is asymmetric information regarding the matching outcome, or potential workers' innate abilities to supply (noncontractible) "performance." This information problem can be alleviated by a screening process.[1] Third, workers' productivity may improve over time through specific bilateral learning and human capital investments that, often, are also noncontractible. An example in which such investments are observed is academics, where some departments allocate research funds to assistant professors on

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[1] See Waldman (1984), Greenwald (1986), and Abe (1994) for the adverse selection phenomenon is labor markets. The personnel data studied by Baker, Gibbs, and Holmstrom (1994) indicate that employers learn about their workers' unobservable characteristics during the relationship and that this learning affects workers' wage profiles.

a nonexclusive basis, which the assistant professor complements with his or her own effort and investment to improve research, administrative, and teaching abilities. These investments are in part relationship specific: the department's investment on the assistant professor is sunk, while the assistant professor's effort, perhaps with the exception of the publication record, is not entirely observable to outsiders.

This article studies a dynamic employment relationship with the three main features mentioned above. When worker performance is not contractible and potential workers retain private information about their matching parameters, a major concern of the employer is to screen out workers with "bad" matching parameters as early as possible, then build up a relationship with a good match and jointly invest to develop specific human capital. The purpose of the present article is to highlight a trade-off that the employer may face in pursuing these objectives; screening efficiency may have to be sacrificed given the employer's postcontract incentives to invest in the worker's specific human capital, or, alternatively, the productivity of the investment technology may have to be reduced in order to induce an efficient screening process. Moreover, when this trade-off is effective, it is likely to influence the worker's career wage profile.

I present a 2-period employer-worker game that starts with the employer's contract (wage) offer to a pool of observationally identical workers. The selected worker then chooses (i) an effort that determines his actual performance and (ii) an investment on his employer-specific human capital simultaneously with the training expenditures of the employer. The employer makes a continuation decision at the end of the first period if the contract is a short-term probationary contract. If she opts for continuation with the incumbent worker, the parties negotiate the terms of the second contract.

All equilibria of this game display an increasing pattern of wages due to the combined impact of matching considerations, information revelation, and the incumbent worker's improved specific human capital, which affects his bargaining power in negotiating future wages. The efficient screening arrangement that attracts only "good" worker types stipulates a relatively high first-contract wage. This relatively high wage could induce a temporary but efficient effort during the probationary contract. However, given also the employer's investment incentives, a "bad" worker type who foresees the equilibrium path may accept the contract, penetrate into the relationship, supplement the employer's investment with his own best reply, generate a sufficient improvement in his specific human capital, and lock the employer in for the second contract. This possibility upsets the screening process. The employer should then either induce a nonscreening equilibrium (offer a contract accepted by all

worker types) or an inefficient screening equilibrium, given the invest-
ment technology in place.

This article highlights a new source of inefficiency in investment on
employer-specific human capital. In labor relationships governed by
incomplete contracts, there is a potential conflict between the employer's
objectives to perform efficient on-the-job screening and train the specific
skills of the workers. This conflict may lead the employer to induce an
equilibrium with inefficient level of specific investment.[2] The model also
provides insights about the determinants of wage profiles within firms.
Comparing the screening and nonscreening equilibria produces a stan-
dard prediction of on-the-job training models (see Demougin and Siow
[1994, 1996] and Malcomson [1997] for references): wage profiles are
steeper for workers who get, and invest more on, training. It also pro-
duces a prediction of sorting models based on private information of the
workers (see Weiss [1995] for an assessment): wage profiles are steeper for
workers who go through probationary contracts than those who do not.
I show that the joint presence of screening considerations and specific
human capital accumulation may produce a steeper wage profile than
predicted by models based on one of these two features and, thus, that the
potential conflict between specific training investments and efficient
screening can further contribute to the "slope" of the wage profile. This
conclusion is more likely to hold if the investment technology is highly
productive.

At a more general level, this article is related to an extensive literature
on dynamic contractual relationships. The problem of designing an in-
complete contracting procedure that provides protection against oppor-
tunism under asymmetric information has been studied by Farrell and

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[2] One reason why the employer-specific investment level may be suboptimal is
complementarity between general and employer-specific abilities. Alternatively, it
may be impossible to decompose human capital investments into their general and
specific components. In the case of bilateral human capital investments, an addi-
tional source of inefficiency arises due to strategic considerations, as one party
would optimally reduce his investment level if the other party invests more. As
Acemoglu and Pischke (1998a) show, labor market imperfections such as turnover
costs and ex post monopsony power can provide employers with some incentives
to invest on workers' general skills. The impact of labor market imperfections is
to transform technologically general skills into specific skills. Acemoglu and
Pischke (1998b) study a two-period model based on the firms' ex post monop-
sony power to explain their expenditures on general training. My focus in this
article is employer-specific investments. Abe (1994) and Prendergast (1992) pro-
vide adverse selection models with investments in specific skills and study equi-
librium labor turnover. Bac and Saglam (1999) study the interplay of unobserv-
able, specific human-capital accumulation, promotion criteria, and managerial
defections. These papers do not consider on-the-job screening in the presence of
bilateral specific investments.

Shapiro (1989) and Bac (1993, 1997).[3] The message of these papers is that using a short-term contracting procedure with potential negotiation for continuation terms is a better protection against opportunistic behavior. Under an incomplete long-term contract that specifies future terms of exchange (wages), one of the parties (the worker) can manipulate non-contractible aspects of exchange (withhold performance) to the expense of the other party (the employer). In such environments, short-term proba-tionary contracts can perform screening and potentially improve perfor-mance by implicitly linking performance to continuation. The new aspect considered in this article is the inclusion of bilateral investments that provide direct benefits to one of the parties (the employer) and indirect benefits to the other (the worker, through improved bargaining power to negotiate better continuation terms).

The article is organized as follows. Section II develops a dynamic game-theoretic model of the employer-worker relationship. The game is analyzed in Section III. Section IV concludes and discusses empirical ramifications of the results. The proofs are gathered in the appendix.

II. Model

An employer demands one unit of labor per period. She faces a pool of potential workers with a reservation wage of $w_R > 0$. Worker perfor-mance, denoted P, is not contractible.[4] A performance-relevant matching parameter, θ, is privately known by the workers. I assume two possible realizations of θ, θ_H and θ_L, with $\theta_H > \theta_L$. Let π denote the probability that a worker is of type θ_H.

There are 2 periods, and no discounting is assumed for simplicity. In each period, worker performance depends on two variables: effort e_t and

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[3] That menus of contracts can induce self-selection and, hence, mitigate asym-metric information and screening problems is well known. A class of dynamic models (see Laffont and Tirole 1988) where output or performance is contractible and information is asymmetric generate the result known as the ratchet effect: potential continuation has a negative effect on present effort incentives. Holm-strom (1982) shows that career concerns can reverse the ratchet effect. In Bac (1993, 1997), potential continuation of the relationship enhances present effort incentives by providing a motive of signaling a good match parameter. The mechanism that generates effort despite contract incompleteness in these models is the agent's expectation of capturing a sufficient continuation surplus; the same mechanism can also produce successful signaling/screening early in the relation-ship. These effects will be operating in the present model as well.

[4] A possible interpretation is that the employer's job offer has idiosyncratic attributes, so that she has to develop a bilateral relationship with a worker to get improved performance in the future. The job can be thought of as a "nonport" job (Doeringer and Piore 1971), partly protected from outside market forces. For simplicity, I assume that the reservation wage w_R does not depend on the privately known matching parameter of the workers.

employer-specific human capital that supplements the matching parameter θ. Given the incumbent worker's type θ, the effort e_t exerted in period t generates performance according to the simple technology $P(\theta, F, e_t) = (\theta + F) + e_t$, where F is the worker's accumulated specific human capital, initially normalized to be zero. The employer observes P and F, but not e_t.

The incumbent worker's specific human capital F can grow through bilateral, noncontractible investments. The worker's and the employer's investments y_W and y_E will generate an improvement in the worker's performance by $F(y_W, y_E)$ in the next period. I assume that the function $F(y_W, y_E)$ is increasing and strictly concave. Investment decisions are made in period one, simultaneously (hence under imperfect information), and observed at the end of period one. The matching parameter θ and specific human capital F are thus substitutes in this model; this specification simplifies the exposition without qualitatively affecting the results.[5]

The parties' objective functions are specified as follows. The employer's per-period utility $u_E = P - w - y_E$ depends directly on the performance of the worker, the wage, and her investment decision. Denoting effort disutility by $d(e)$, the corresponding expression for the incumbent worker is $u_W = w - d(e) - y_W$.

In the last period, noncontractibility of performance blocks the employer's way in providing effort incentives, hence the worker will withhold effort and offer the performance $\theta + F(y_W, y_E)$. However, first-period effort that temporarily improves performance may be positive, as I show, thanks solely to the incumbent worker's incentive to signal his type.

The contractible variables in this model are the wage w and the duration of contracts. Thus, the relationship will be governed either by a "long-term" contract $\{w_1, w_2\}$ where the wages for the 2 periods are specified (possibly including a high breach penalty to ensure that the parties do not renege on its terms) or a "short-term" contract $\{w_1\}$ that includes no commitments for continuation. Here, commitment for continuation to period two is a dominated option for the employer, and accordingly, I focus on short-term contractual arrangements. As the analysis in Section III will make clear, the only reason why the incumbent worker accepts the short-term contract offer and invests on specific human capital despite the hazard of termination is the anticipated link to his second-period wage: the worker's performance and investment y_W

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[5] The potential conflict between the screening and investment motives of the employer exists under complementarity as well, but the analysis of this case is slightly more complex.

signal information and increase his value for the employer, thus also his bargaining power at the contract-renewal stage. A long-term contract that guarantees continuation at the prespecified wage w_2 eliminates this link and, thereby, the incumbent worker's incentive to invest on employer-specific skills.[6]

Thus, the sequence of events under short-term contracting is as follows. The employer makes the initial offer, workers make acceptance decisions, and the employer picks one among those who accept. During the first period, the worker chooses (e_1, y_W), and the employer chooses y_E, paying the wage w_1. The employer observes performance and investments as the first period expires and updates her beliefs about the incumbent worker's type. The revised probability that she faces a θ_H-worker given P_1 and y_W is denoted $\mu(\theta_H | P_1, y_W)$. At this stage, the employer either keeps the incumbent worker ($b = 1$) or terminates and switches to another worker ($b = 0$). If the employer picks the first option, the parties proceed to the negotiation stage where their relative bargaining power determines the wage for the second contract.[7] The bargaining power may be split between the incumbent worker and the employer at the interim-contract renewal stage because parity between the incumbent worker and outsiders may not obtain due to transmission of matching information and accumulation of specific human capital. The model thus captures a salient feature of real-life employment relationships: their transformation into a bilateral monopoly.

Below I postulate a solution to the interim negotiation problem and

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[6] The observation that long-term contracts are (weakly) dominated does not depend on the presence of an investment technology. Long-term contracts provide protection against opportunism when there is external uncertainty and all trade-relevant variables are contractible or there are contractible sufficient statistics for the relevant variables. If, as in the present model, certain key aspects of trade are not contractible, the employer can only be worse off by committing herself to continuation and paying prespecified wages because the worker can manipulate noncontractible performance. See Bac (1993, 1997) for a discussion of this phenomenon and Bac (1998) for an application to a buyer-seller context.

[7] The evolution of the parties' relative bargaining power is thus an important component of the analysis. I do not assume that the employer retains all the bargaining power in all circumstances. To be precise, the employer has all the bargaining power whenever there is at least one other worker available who is observationally identical to the incumbent worker. The employer can induce Bertrand-type competition among the seemingly identical workers and capture the surplus. If the employer cannot induce such competition, the employer and the incumbent worker will each have some bargaining power. In this setting, no individual worker ever has all the bargaining power with respect to the employer, for the employer is unique and trade with her promises a net nonnegative surplus. The employer has all the bargaining power at the initial stage because she faces a pool of seemingly identical workers.

later incorporate this solution into the definition of the equilibrium of the extensive-form game. Suppose that the employer terminates her relationship and hires another worker. Since performance is not contractible and there is 1 period to go, the employer will not be able to screen out workers with bad matching parameters. Accordingly, the employer's optimal wage offer leaves all worker types indifferent, that is, $w_2 = w_R$. This yields $U_E^X = \pi\theta_H + (1 - \pi)\theta_L - w_R$ as the expected value of the employer's outside option. Given investments y_W, y_E and the employer's beliefs μ, any wage w_2 that yields more than U_E^X would make a positive continuation surplus for the employer. On the other hand, since the incumbent worker's disagreement utility is the reservation wage w_R, he will obtain a positive surplus from any wage above w_R. Therefore any negotiated second-period wage $w_2(\mu, y_W, y_E)$ from the interval $[w_R, w_R + (\theta_H - \theta_L)(\mu - \pi) + F(y_W, y_E)]$ is mutually beneficial. Note that if the incumbent worker has signaled no type information nor accumulated any specific human capital, $\mu = \pi, F = 0$, and the employer is indifferent between continuation and termination, which implies that the only possible second period wage is $w_2 = w_R$. The employer will terminate the relationship if $F = 0$ and $\mu = 0$ (the worker reveals a bad match and no investment is made).

The wage $w_2(\mu, y_W, y_E)$ represents the anticipated outcome of bargaining. In internal labor markets, it may be determined by administrative rules and custom that govern the pricing of labor. When continuation is mutually beneficial, thus, chosen by the employer, I assume that the negotiated wage $w_2(\mu, y_W, y_E)$ splits the total expected surplus $(\theta_H - \theta_L)(\mu - \pi) + F(y_W, y_E)$ proportionately. The share β goes to the incumbent worker, and the share $1 - \beta$ goes to the employer. Note that the case $\beta = 0.5$ corresponds to the Nash bargaining solution when $\mu = 0$ or $\mu = 1$.

The expected utilities of the incumbent worker and the employer can respectively be written as follows:

$$U_W = w_1 - d(e_1) - y_W + bw_2(\mu, y_W, y_E) + (1 - b)w_R, \qquad (1)$$

$$U_E = P_1 - w_1 - y_E + bV + (1 - b)[\pi\theta_H(1 - \pi)\theta_L - w_R]. \qquad (2)$$

In (2), $V = \mu\theta_H + (1 - \mu)\theta_L + E\{F(y_W, y_E) - w_2(\mu, y_W, y_E)\}$ is the employer's second period expected utility. Expected first-period performance is $P_1 = \pi\theta_H + (1 - \pi)\theta_L + e_1^*$ if $\{w_1\}$ is a nonscreening contract and $P_1 = \theta_H + \hat{e}_1$ if it is a screening contract that attracts only θ_H-workers.

The solution concept for this game is Perfect Bayesian Equilibrium (PBE). Given her updated beliefs, the employer's continuation decision

must be optimal; investment decisions during the first period must be best replies to each other, and the worker's acceptance and effort choices (contingent on being selected) must be optimal. The employer's initial choice of contractual arrangement must also be optimal, given the induced continuation equilibrium. The employer's belief system is an important component of equilibrium construction, postulated here as $\mu(\theta_H|P_1, y_W) = 1$ if both $P_1 \geq \bar{P}$ and $y_W \geq \bar{y}$, and $\mu(\theta_H|P_1, y_W) = 0$ otherwise. I impose the Intuitive Criterion on beliefs off the equilibrium path, which also serves to determine $\bar{P}$ and $\bar{y}$ endogenously. According to these beliefs, on observing a performance or investment that falls short of the threshold $\bar{P}$ or $\bar{y}$, the employer believes that she faces a θ_L-worker.[8] A standard tie-breaking assumption will ensure that a θ_L-worker rejects a contract proposal if he is indifferent between accepting and rejecting.

Since the two worker types are initially observationally identical and have the same reservation wage, any contract $\{w_1\}$ that is accepted by a θ_L-worker will also be accepted by a θ_H-worker. The latter has a matching advantage in any continuation equilibrium. Thus, potential types of equilibria include those in which θ_L-workers are screened out and those in which both types of workers accept the initial contract to work for at least one period. The latter type of (nonscreening) equilibria can further be classified according to whether the worker types "separate" or "pool together" at the end of the first contract (whether $\mu \in \{0, 1\}$ or $\mu = \pi$). Since a screening PBE cannot be of the pooling type, the game has three potential types of PBE: screening-separating, nonscreening-separating, and nonscreening-pooling. The last of these three, as I show below, cannot arise under the Intuitive Criterion given the matching advantage of the θ_H-worker.

III. Analysis

Consider the interim contract-renewal stage. If $\mu = 0$ so that the employer is convinced that her partner is of type θ_L, she will opt for continuation only if the corresponding second-period surplus exceeds her expected utility from switching to another worker given the observed investment levels y_{WL} and y_E. This can be stated as $\pi\theta_H + (1 - \pi)\theta_L < F(y_{WL}, y_E) + \theta_L$, or

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[8] In the proof of proposition 1, I show that the degenerate belief system postulated above is consistent with the Intuitive Criterion. Given any nondegenerate belief system where $\mu(\theta_H|P_1, y_W)$ is increasing in P_1 and y_W (i.e., according to which a better performance and a higher investment level does not decrease the probability that the employer faces a θ_H-worker) and given a strategy profile that is consistent with these beliefs, the θ_H-worker can credibly and beneficially signal his type by deviating to a strategy (e, y_W) due to the performance gap $\theta_H - \theta_L$ between the two worker types.

$$\theta_H - \theta_L < \frac{F(y_{WL}, y_E)}{\pi}. \tag{3}$$

The expected continuation surplus is $F(y_{WL}, y_E) + (1 - \pi)(\theta_H - \theta_L)$ if $\mu = 1$ and $F(y_{WL}, y_E) - \pi(\theta_H - \theta_L)$ if $\mu = 0$. Then according to the proportional solution, the negotiated wages are

$$w_2(1, y_{WH}, y_E) = \beta[F(y_{WH}, y_E) + (1 - \pi)(\theta_H - \theta_L)] + w_R$$

and

$$w_2(1, y_{WL}, y_E) = \beta[F(y_{WL}, y_E) - \pi(\theta_H - \theta_L)] + w_R,$$

for $\mu = 1$ and $\mu = 0$, respectively. Recall that investment decisions are made simultaneously, before the employer observes performance during the first contract. Thus, given a pair of investment levels and the employer's beliefs μ, at the stage where investment decisions are made, the expressions of the worker's and the employer's expected utilities are, respectively,

$$U_{Wi}^I = -y_{Wi} + bw_2(\mu, y_{Wi}, y_E) + (1 - b)w_R,$$

$$U_E^I = -y_E + bV + (1 - b)[\pi\theta_H + (1 - \pi)\theta_L - w_R].$$

First, I construct below a nonscreening PBE with continuation to period two and show that any such PBE must be of the separating type. That is, the employer learns the incumbent worker's type at the end of period one (though she is incompletely informed at the investment stage) and opts for continuation no matter the realized type of the incumbent worker. The following optimality conditions must hold. The θ_H-worker's equilibrium investment strategy satisfies

$$y_{WH}^* > 0 \quad \text{if } \beta \frac{\partial F(y_{WH}^*, y_E^*)}{\partial y_W} = 1. \tag{4}$$

I confine the analysis to the case $w_2(1, y_{WH}^*, y_E^*) - w_R \geq y_{WH}^*$ so that $U_{WH}^I \geq w_R$ for $b = 1$. Otherwise, if $U_{WH}^I < w_R$ the θ_H-worker would optimally set $y_{WH} = 0$ and guarantee himself the reservation wage w_R. In equilibrium, the θ_L-worker determines y_{WL}^* according to

$$y_{WL}^* > 0 \quad \text{if } \beta \frac{\partial F(y_{WL}^*, y_E^*)}{\partial y_W} = 1$$

and

$$\beta[F(y^*_{WL}, y^*_E) - \pi(\theta_H - \theta_L)] - w_R \geq y^*_{WL}, \qquad (5)$$

and $y^*_{WL} = 0$ otherwise. Note that the θ_L-worker's optimal investment strategy is contingent on the employer's continuation strategy. He will choose a positive investment $y^*_{WL} > 0$ to negotiate the wage $w_2(0, y^*_{WL}, y^*_E)$ and stay for the second period only if this option promises a positive return, as stated in (5). Comparing (5) and (4) reveals that $y^*_{WH} = y^*_{WL}$ if $y^*_{WL} > 0$. Note also that $w_2(0, y^*_{WL}, y^*_E) > w_R$ if and only if $F(y^*_{WL}, y^*_E) > \pi(\theta_H - \theta_L)$, that is, if and only if the continuation surplus with a θ_H-worker is positive, hence (3) is implied if (5) holds. As for the employer's optimal investment y^*_E, it satisfies the first-order condition

$$1 = (1 - \beta) \frac{\partial F(y^*_{Wi}, y^*_E)}{\partial y_E}. \qquad (6)$$

Let $\phi(\cdot)$ denote the inverse of $d(\cdot)$, the strictly concave effort disutility function. Any nonscreening equilibrium has the properties listed below.

PROPOSITION 1.

i) A nonscreening PBE induces continuation of the relationship through the second period with both worker types. The θ_L-worker exerts zero effort while the θ_H-worker exerts the effort $e^*_H = \max\{0, \bar{e}_L - (\theta_H - \theta_L)\}$ where

$$\bar{e}_L = \phi(w_2(1, y^*_{Wi}, y^*_E) - w_2(0, y^*_{Wi}, y^*_E)), \qquad (7)$$

which signals his type. The employer's first-period strategy is to offer the wage

$$w^*_1 = 2w_R + y^*_{Wi} - w_2(0, y^*_{Wi}, y^*_E). \qquad (8)$$

ii) Any nonscreening contract that induces continuation with only the θ_H-worker is dominated by contracts that perform screening.

iii) Application of the Intuitive Criterion implies that the worker types always separate as the first contract expires. That is, all PBE are of the separating type, and $w^*_1 < w_R$.

A contract $\{w^*_1\}$ that is accepted by both worker types induces continuation to the second period with probability one, for no worker would accept the initial offer below his reservation wage if the employer had an incentive to terminate the relationship. The equilibrium offer wage in (8) is derived from θ_L-workers' indifference condition, as the employer can always modify the offer wage to bind the participation constraint of

θ_L-workers. The incumbent θ_H-worker obtains a positive surplus. Using (8) and the definition of $w_2(\mu, y_W, y_E)$, the employer's expected utility in a nonscreening PBE can be written as

$$
\begin{aligned}
U_E &= \pi[2\theta_H + e_H^* + F(y_{Wi}^*, y_E^*)] + (1 - \pi)[2\theta_L + F(y_{Wi}^*, y_E^*)] \\
&\quad - \pi[w_2(1, y_{Wi}^*, y_E^*) - w_2(0, y_{Wi}^*, y_E^*)] - w_R - y_E^* - y_{Wi}^* \\
&= 2[\pi\theta_H + (1 - \pi)\theta_L - w_R] + F(y_{Wi}^*, y_E^*) \\
&\quad - \pi\beta(\theta_H - \theta_L) + \pi e_H^* - y_E^* - y_{Wi}^*,
\end{aligned}
\tag{9}
$$

where $e_H^* = max\{0, \bar{e}_L - (\theta_H - \theta_L)\}$. The employer invests y_E^* on the incumbent worker's specific human capital under the risk that the investment may lock her in with a (potentially improved) θ_L-worker. A by-product of the process is a positive effort e_H^* by the θ_H-worker who signals his type during the first period. Combining the result of parts i and ii of proposition 1 yields the dynamics of wages: $w_1 < w_R < w_2$.

The critical condition for the existence of a nonscreening PBE with unconditional continuation is (5). The θ_L-worker's optimal investment on specific human capital must be sufficiently productive to cover at least his investment cost, by improving his bargaining power and generating a higher second-period wage. Otherwise, the θ_L-worker will choose y_{WL}^* = 0, and the employer will opt for switching at the end of period one. But then inducing a nonscreening PBE cannot be optimal, as stated in part iii of proposition 1.

Consider now screening PBE where the corresponding strategies are denoted through "hats." As mentioned, the employer cannot screen out θ_L-workers through a first-period wage above w_R. She thus has to choose an appropriate wage $w_1 < w_R$ that attracts only θ_H-workers. The employer's optimal investment $\hat{y}_E$ maximizes (2) given $\hat{y}_{WH}$, where $\pi\theta_H + (1 - \pi)\theta_L$ should now be replaced by θ_H, and $V = \theta_H + F(\hat{y}_{WH}, \hat{y}_E) - w_2(1, \hat{y}_{WH}, \hat{y}_E)$. Hence, $\hat{y}_E$ satisfies the equilibrium condition

$$
1 = \frac{\partial F(\hat{y}_{WH}, \hat{y}_E)}{\partial y_E} - \frac{\partial w_2(1, \hat{y}_{WH}, \hat{y}_E)}{\partial y_E},
\tag{10}
$$

while $\hat{y}_{WH}$ satisfies (4) as in the nonscreening PBE. Obviously, a screening PBE must involve continuation (with the θ_H-worker). Otherwise, since $w_1 < w_R$, no θ_H-worker would accept the initial contract. A θ_H-worker accepts the wage below his reservation wage because he expects (as fulfilled in equilibrium) that he will be able to capture an offsetting surplus $w_2(1, \hat{y}_{WH}, \hat{y}_E) - w_R$ from continuation through the second period.

PROPOSITION 2. In a screening PBE, the initial contract $\hat{w}_1 < w_R$ is

accepted by only θ_H-workers. In the first period, the incumbent θ_H-worker's strategy is $\hat{e}_H = max\{0, \bar{e}_L - (\theta_H - \theta_L)\}$ where

$$\bar{e}_L = \phi(\hat{w}_1 - 2w_R - \hat{y}_{WH} + w_2(1, \hat{y}_{WH}, \hat{y}_E)), \qquad (11)$$

while θ_L-workers are indifferent between rejecting and accepting the contract, then exerting the effort $\bar{e}_L$ and investing $\hat{y}_{WH}$. The employer can always guarantee herself the expected utility level

$$\underline{U}_E = 2[\theta_H - w_R] + F(\hat{y}_{WH}, \hat{y}_E) - \hat{y}_{WH} - \hat{y}_E. \qquad (12)$$

The lower bound to the employer's screening PBE utility obtains when the θ_H-worker credibly signals his type through zero effort. This is not necessarily the maximum expected utility of the employer. As I show below, the alternative option of inducing $\hat{e}_H > 0$ has a cost in the form of a higher first-period wage but a benefit in the form of improved first-period performance. The corresponding equilibrium conditions are as follows: $\hat{e}_H = \bar{e}_L - (\theta_H - \theta_L) > 0$, $\hat{y}_E$ must satisfy (10), and $\hat{w}_1$ must satisfy

$$1 = \frac{\partial \phi(\hat{w}_1 - 2w_R - \hat{y}_{WH} + w_2(1, \hat{y}_{WH}, \hat{y}_E))}{\partial d}. \qquad (13)$$

Now an upper bound $\bar{w}_1 < w_R$ on first-period wages $\hat{w}_1$ that perform screening *and* induce a positive effort is implied by the possibility that a θ_L-worker accepts the contract and locks the employer in for the second period by investing his best reply to $\hat{y}_E$, denoted $y_{WL}(\hat{y}_E)$. Note that $y_{WL}(\hat{y}_E) = \hat{y}_{WH}$, that is, the two worker types' investments are the same, because the pair $(\hat{y}_{WL}, \hat{y}_E)$ constitutes mutual best replies. Acceptance of the initial contract by θ_L-workers would upset the screening PBE, however. There is a maximal wage $\bar{w}_1$ that performs screening and induces the effort $\hat{e}_H$ by the θ_H-worker, while making θ_L-workers indifferent between rejecting and accepting $\{\bar{w}_1\}$ to invest $y_{WL}(\hat{y}_E) = \hat{y}_{WH}$. Thus the latter strategy must yield θ_L-workers zero expected surplus at the wage $\bar{w}_1 = 2w_R + \hat{y}_{WH} - w_2(0, \hat{y}_{WH}, \hat{y}_E)$. Using this wage expression and strict concavity of $\phi(\cdot)$, a necessary condition for an interior solution satisfying (13) and $\hat{w}_1 \leq \bar{w}_1 < w_R$ can be derived by letting $\hat{w}_1 \to \bar{w}_1$ in (13):

$$\frac{\partial \phi(w_2(1, \hat{y}_{WH}, \hat{y}_E) - w_2(0, \hat{y}_{WH}, \hat{y}_E))}{\partial d} < 1. \qquad (14)$$

There exists a wage $\hat{w}_1 \leq \bar{w}_1$ satisfying (13) if (14) holds.[9] Then, condition (10), which determines the employer's equilibrium investment, simplifies to $1 = \partial F(\hat{y}_{WH}, \hat{y}_E)/\partial y_E$, and the employer's equilibrium expected utility is

$$U_E = 2\theta_H - \hat{w}_1 - w_R + \hat{e}_H + F(\hat{y}_{WH}, \hat{y}_E) - w_2(1, \hat{y}_{WH}, \hat{y}_E) - \hat{y}_E. \quad (15)$$

To induce effort during the screening process, the employer must offer a wage significantly higher than $\hat{w}_1$ (the wage that induces the zero-effort screening PBE). This is beneficial for the employer if $\hat{e}_H - \hat{w}_1 > w_2(1, \hat{y}_{WH}, \hat{y}_E) - w_R - \hat{y}_{WH} > 0$, that is, if the equilibrium effort $\hat{e}_H$ and the performance so induced are sufficiently high to offset the wage differential $\hat{w}_1 - \underline{\hat{w}}_1$. I stress the following point: even though $U_E > \underline{U}_E$, so that efficient screening stipulates inducing a screening equilibrium with positive effort, this may be impossible because $\hat{w}_1$ as defined through (13) may well exceed $\bar{w}_1$. The following result obtains.

PROPOSITION 3.   It may be impossible to induce the efficient screening equilibrium given the employer's postcontract investment incentives and anticipated continuation decision. In this case, the employer offers a contract $\{\hat{w}_1\}$ that distorts the θ_H-worker's effort $\hat{e}_H$. As a result, her expected utility from the screening PBE falls, and she may choose to induce either a zero-effort equilibrium or a nonscreening equilibrium.

The employer's most preferred outcome is certainly to build a relationship with a θ_H-worker from the outset and invest jointly on her partner's specific human capital for continuation. The most efficient way of screening may involve getting some improved performance in the first period from the θ_H-worker by offering a relatively high first-period wage $\hat{w}_1$. However, proposition 3 states that the employer's investment incentives may well upset this objective by attracting θ_L-workers. In other words, $\hat{w}_1$ may exceed the minimal screening wage $\bar{w}_1$. A θ_L-worker may accept the wage $\hat{w}_1$ and lock the employer in for the second period. The employer's investment $\hat{y}_E$ and the θ_L-worker's investment $y_{WL}(\hat{y}_E) = \hat{y}_{WH}$ would generate a sufficient improvement in his specific human capital so that ex post the employer has no choice but to continue with the θ_L-worker. The employer, then, cannot induce a screening PBE with efficient effort. She has to distort $\hat{w}_1$, hence the effort $\hat{e}_H$, downward, which decreases her expected utility.

The problem identified above may lead the employer to commit her-

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[9] Condition (14) is likely to hold if the differential utility $U^L_{WH} - U^I_{WL}$, as viewed from the investment stage, is large enough. One of the factors affecting the utility differential $U^I_{WH} - U^I_{WL}$ is the "innate" performance gap, $\theta_H - \theta_L$, through the support of the set of mutually beneficial second-period wages containing w_2.

self, if possible, to an investment strategy sufficiently below $\hat{y}_E$ and make that commitment public at the outset. Modifying the investment technology to decrease its productivity is another possibility. This will relax the screening constraint and allow for a higher maximal screening wage $\bar{w}_1$, thus potentially reducing the effectiveness of the conflict between investment and efficient screening. Proposition 4 below considers the rather extreme case of zero productivity to show that the screening constraint can be relaxed this way. Since all PBE are of the separating type by proposition 1, the employer will never choose continuation with a θ_L-worker because the expected matching value of an outsider, $\pi\theta_H + (1 - \pi)\theta_L$, exceeds θ_L. Then a nonscreening contract must induce continuation with only the θ_H-worker, and the corresponding first-period wage is $w_1 = w_R$.

PROPOSITION 4. In the absence of investments on specific human capital, (i) any increasing wage profile with $w_1 < w_R$ induces a screening PBE (now the maximal screening wage is $\bar{w}_1 = w_R$); and (ii) in a screening PBE, the θ_H-worker exerts the effort $e_H^S = \bar{e}_L - (\theta_H - \theta_L)$, where $\bar{e}_L = \phi(w_1^S - w_R + \beta(\theta_H - \theta_L))$, and the optimal screening wage w_1^S satisfies $1 = \partial\phi(w_1^S - w_R + \beta\pi(\theta_H - \theta_L))/\partial d$. Such an equilibrium exists if

$$1 > \frac{\partial\phi(\beta\pi(\theta_H - \theta_L))}{\partial d}, \tag{16}$$

which is weaker than the corresponding condition in the presence of an investment technology.

IV. Conclusion

This article shows that employers' incentives to invest on specific human capital jointly with incumbent workers may conflict with their objective to induce an efficient screening process. A higher initial wage must be offered when efficient screening stipulates that workers on short-term contracts exert effort in signaling a good match parameter, yielding temporarily improved worker performance as a by-product. This high wage may upset the employer's screening objective, however. Workers with a bad match parameter may find it worthwhile to penetrate into the relationship and invest and generate sufficient improvement in their specific human capital to lock the employer in for the future. Then, since she cannot induce the efficient screening equilibrium, the employer would have two options left. Either she induces an inefficient screening equilibrium or she credibly decreases the productivity of the technology generating specific human capital. This potential explanation for subop-

timal expenditures on on-the-job training is entirely different from those based on "inappropriable rents" in firms' investments on young employees.

All equilibria of this model display an increasing pattern of wages.[10] Many other features of the equilibria of this model accord well with the empirical studies that suggest a significant combined effect of matching, screening, and human capital investments on wage profiles (e.g., Brown 1989; Topel 1991; and Topel and Ward 1992). Sicherman and Galor (1990) present evidence that worker-firm matching is resolved and specific capital is accumulated early in a worker's career. The personnel data analyzed by Baker et al. (1994) reveal that learning and human capital accumulation affect wage profiles along careers within firms. A message of the present analysis is that empirical studies aiming at explaining wage profiles should take into account the potential distortion introduced by the conflict between employers' objectives to screen efficiently while investing on specific human capital. I have shown that this distortion can contribute to the steepness of the wage profile, and thus that the simultaneous presence of these two objectives (screening and investing) should be consistent with a wide range of wage profiles with different slopes.

One implication of this model is that a more productive investment technology is likely to generate a steeper wage profile when matching and screening have important efficiency consequences. Another implication is that the larger the "innate performance gap" between potential worker types—thus the more significant the adverse selection problem—the steeper is the wage profile, keeping other factors constant. The second prediction is also derived in on-the-job training models with turnover costs (see Waldman 1984; Greenwald 1986; and Demougin and Siow 1996). It finds empirical support in Loh's (1994) findings that workers have significantly steeper wage profiles in jobs with probationary contracts and that a steep wage profile is a good indicator of whether the job has a probationary contract. The first prediction awaits a rigorous empirical test, ideally using personnel data from firms in order to generate reliable estimates for the productivity of both the worker's and the employer's investments on specific human capital. The most important practical problem lies in assessing the joint and isolated effects of matching concerns and bilateral human capital investments on the wage profile. This model implies that the joint effect can be substantially larger than the isolated effects.

The model can be modified or extended in several directions. An important modification is to replace specific with general human capital and introduce labor market imperfections (which, as Acemoglu and

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[10] Prendergast (1999) surveys the literature explaining and empirically verifying the rising pattern of wages throughout careers.

Pischke [1998*a*, 1998*b*] have shown, are necessary to generate positive general investments by the employer). The reservation wage of the worker would then be increasing in his stock of general human capital, but continuation would be mutually beneficial and the employer would capture a return on her investment. Labor market imperfections drive a wedge between the minimum wage for which the employee will work and the maximum wage the employer will pay. Negotiations, as in the present model, determine where within the wedge the wage will lie. Though these features are similar, the analysis in the case of general human capital differs in two important respects. First, screening becomes more problematic because improved general human capital increases the worker's reservation wage: workers with poor matching parameters may penetrate into the relationship, get some investment on their general human capital, and later switch away if switching costs are not too high. Second, given a matching outcome, the continuation surplus and, therefore, the employer's incentives to invest on general human capital are determined by the significance of labor market imperfections. (In the case of specific human capital, these are determined by the productivity of the investment technology.) Though the distinction between specific and general human capital vanishes in the limit where the two contracting parties are completely locked in and isolated from market forces, for intermediate degrees of labor market imperfections (with nonprohibitive switching costs), the incumbent worker's improved outside option limits the continuation surplus and erodes the employer's incentives to invest on general human capital. Thus the shape of the wage profile and the effectiveness of the potential conflict between the employer's matching motive and investment incentives would depend on an additional variable: the degree of labor market imperfections. An extension of the present model in this direction may identify new factors shaping wage profiles in firms.

Appendix

Proofs

Proof of proposition 1.
i) Fixing other players' equilibrium strategies as described in the proposition statement, a θ_L-worker who puts in zero effort expects the utility

$$U_{WL} = w_1^* - y_{Wi}^* + w_2(0, y_{Wi}^*, y_E^*) \geq 2w_R. \qquad (A1)$$

It is possible to define an effort level $\bar{e}_L$ for the θ_L-worker, such that $\bar{e}_L$ is just enough to close the innate performance gap $\theta_H - \theta_L$ and imitate the θ_H-worker's performance, provided that the employer interprets the resulting performance $\bar{e}_L + \theta_L \geq \bar{P}$ as coming from a θ_H-worker. If this imitation strategy of the θ_L-worker is not beneficial, then the two worker types must separate in equilibrium. The θ_L-worker will be indifferent

between exerting $\bar{e}_L$ to imitate the performance level $P_H^* = \bar{P}$ and playing his zero-effort equilibrium strategy if

$$w_1^* - y_{Wi}^* + w_2(0, y_{Wi}^*, y_E^*) = w_1^* - y_{Wi}^* - d(\bar{e}_L) + w_2(1, y_{Wi}^*, y_E^*).$$

Inverting $d(\bar{e}_L)$ and solving yields the expression for $\bar{e}_L$ given in (7). This effort level, as I show below, will be used in determining the threshold performance level $\bar{P}$. On the other hand, given $\bar{P}$, the θ_H-worker's optimal effort strategy is $e_H^* = max\{0, \bar{P} - \theta_H\}$. I can now define the threshold performance level in the employer's belief system as $\bar{P} = \bar{e}_L + \theta_L$, which, if $e_H^* > 0$, is also equal to $e_H^* + \theta_H$. Therefore, in any separating PBE with positive effort, $\bar{e}_L + \theta_L = e_H^* + \theta_H$. As for the θ_L-worker's equilibrium strategy, $e_L^* = 0$ is an optimal effort strategy by the tie-breaking assumption. Exerting the maximal effort $\bar{e}_L$ to imitate the θ_H-worker yields the same reservation utility w_R, whereas all other effort strategies generate a lower expected utility.

Optimality of the investment strategies given the belief system of the employer is discussed in the text. I show below that the postulated belief system is consistent with the Intuitive Criterion. Note that P_H^* is a convincing signal that $\theta = \theta_H$. If the threshold performance level $\bar{P}$ were above P_H^*, then the θ_H-worker could still send the performance signal P_H^* that the θ_L-worker could not and which, by the Intuitive Criterion, should lead to $\mu = 1$. As for the threshold investment level $\bar{y}$ in the employer's beliefs, given $\bar{P} = P_H^*$, suppose by way of contradiction that $\bar{y} > y_{Wi}^*$ and $\mu = 1$ only for $y_{Wi} \geq \bar{y}$ is part of a belief system satisfying the Intuitive Criterion. Let the employer's best reply to $\bar{y}$ be $y_E^*(\bar{y})$. Note, however, that $\bar{y} > y_{Wi}^*$ is not a best reply to $y_E^*(\bar{y})$. These beliefs are forcing the θ_H-worker to invest $\bar{y}$, even more than y_{Wi}^*, in order to signal his type. If the θ_H-worker deviates to his best reply $y_{WH}^*(y_E^*(\bar{y}))$ and keeps providing the performance $P_H^* \geq \bar{P}$, this deviation is bad only for the θ_L-worker, and according to the Intuitive Criterion, $\mu = 1$. It follows that the threshold investment level $\bar{y}$ in the employer's beliefs should not exceed y_{Wi}^*, which is a best reply to y_E^* for both worker types, as stipulated by conditions (4), (5), and (6).

The optimal contract $\{w_1^*\}$ in a nonscreening PBE satisfies (8). To see this, note that the θ_H-worker's equilibrium expected utility and participation constraint are

$$U_{WH} = w_1 - d(e_H^*) - y_{Wi}^* + w_2(1, y_{Wi}^*, y_E^*) \geq w_R. \qquad (A2)$$

Since $\bar{e}_L$ is not affected by w_1 (see [7]), w_1 should be chosen as low as possible. The lower bound for w_1 in a nonscreening contract binds the participation constraint (A1) of the θ_L-worker, which yields the result stated in (8), and (5) implies $w_1^* < w_R$. Note that $U_{WL} \geq w_R$ because $e_H^* \leq \bar{e}_L$.

ii) Suppose that (3) does not hold, so that the employer terminates the relationship if $\mu = 0$. The θ_L-worker's corresponding strategies are y_{WL}^*

$= 0$ and $e_L^* = 0$, which yields the utility $U_{WL} = w_1 + w_R$. The θ_H-worker determines his equilibrium effort according to $e_H^* = max\{0, \bar{e}_L - (\theta_H - \theta_L)\}$, where

$$\bar{e}_L = \phi(w_2(1, y_{Wi}^*, y_E^*) - w_R - y_{Wi}^*).$$

As in case (i), exerting the effort $\bar{e}_L$ to imitate the θ_H-worker's performance yields the θ_L-worker the expected utility he would obtain by setting effort equal to zero. Since $\bar{e}_L$ is independent of w_1, the employer should again set w_1 as low as possible, which in this case is $w_1^* = w_R$. Decreasing w_1 by arbitrarily small ε would then screen out the θ_L-worker without significantly affecting equilibrium effort and generate an improvement of $(1 - \pi)(\theta_H - \theta_L)$ in expected first-period performance. Nonscreening contracts are therefore dominated.

iii) Given the θ_H-worker's advantage in providing performance, the Intuitive Criterion eliminates all potential pooling equilibria (where performance and investment strategies are not informative). To satisfy the Intuitive Criterion, the employer's belief system must put zero probability on $\theta = \theta_L$ when a sufficiently high performance is observed. It is impossible to construct a pooling equilibrium belief system that satisfies this requirement.

Since any nonscreening PBE must be of the type presented in part (i), I conclude that $w_1^* < w_R$. On the other hand, it is impossible to induce a screening equilibrium through $w_1 > w_R$, for a θ_L-worker would accept the offer, set effort and investment equal to zero, and return to his outside option as the contract expires. Therefore, $w_1^* < w_R$ in any PBE.   Q.E.D.

Proof of proposition 2.   The employer's decision to extend the relationship to period two is clearly optimal whenever $\mu = 1$. Determining the threshold performance and investment levels as $\bar{P} = \hat{P}_H$ and $\bar{y} \leq \hat{y}_{WH}$ for beliefs off the equilibrium path satisfies the Intuitive Criterion and is consistent with the equilibrium strategies presented below. The details are omitted, for they follow from arguments similar to those presented in case i of proposition 1. The investment level $\hat{y}_{WH}$ satisfies (4), and $\hat{P}_H = \theta_H + \hat{e}_H$ where $\hat{e}_H = max\{0, \bar{e}_L - (\theta_H - \theta_L)\}$, and $\bar{e}_L$ is defined by (11). Since $w_2(1, \hat{y}_{WH}, \hat{y}_E)$ and $\hat{y}_{WH}$ are unique, $\bar{e}_L$ is unique and so is $\hat{e}_H$. The employer can always induce a zero-effort equilibrium through the wage

$$\hat{w}_1 = 2w_R + \hat{y}_{WH} - w_2(1, \hat{y}_{WH}, \hat{y}_E),$$

binding the θ_H-worker's participation constraint, which yields her the expected utility level given in (12).   Q.E.D.

Proof of proposition 3.   The θ_H-worker's effort strategy in a screening PBE is $\hat{e}_H = \bar{e}_L - (\theta_H - \theta_L)$, where $\bar{e}_L = \phi(\hat{w}_1 - w_R - \hat{y}_{WH} + \beta F(\hat{y}_{WH}, \hat{y}_E) + \beta\pi(\theta_H - \theta_L))$. The optimal first-period wage $\hat{w}_1$ balances the costs and benefits, maximizing the employer's expected continuation utility:

$$1 = \frac{\partial \phi(\hat{w}_1 - w_R - \hat{y}_{WH} + \beta F(\hat{y}_{WH}, \hat{y}_E) + \beta \pi (\theta_H - \theta_L))}{\partial d}. \quad (A3)$$

However, $\hat{w}_1$ must satisfy an additional condition to screen out θ_L-workers. Let $y_{WL}(\hat{y}_E)$ maximize $\beta F(y_{WL}, \hat{y}_E) - y_{WL}$ given $\hat{y}_E$. Note that $y_{WL}(\hat{y}_E) = \hat{y}_{WH}$ because $\hat{y}_{WH}$ satisfies the same equilibrium condition. Then the screening constraint becomes $\hat{w}_1 \leq \bar{w}_1$, where

$$\bar{w}_1 = w_R + \hat{y}_{WH} - \beta[F(\hat{y}_{WH}, \hat{y}_E) - (1 - \pi)(\theta_H - \theta_L)]. \quad (A4)$$

A first-period wage that satisfies both (A3) and $\hat{w}_1 \leq \bar{w}_1$ may not exist. In that case, the employer has to distort w_1 downward to satisfy this condition and induce a lower equilibrium effort, which reduces her expected utility. The resulting expected utility may be less than what she obtains in a screening PBE without effort, or the utility in (9) corresponding to a nonscreening PBE.   Q.E.D.

Proof of proposition 4.

i) Since all PBE are of the separating type and the employer sets $b = 0$ if $\mu = 0$, the θ_L-worker's expected utility from accepting the contract is simply w_1. Therefore, $\bar{w}_1 = w_R$, and any wage $w_1 < w_R$ induces a screening PBE.

ii) Derivation of strategies and beliefs in a screening PBE follow the arguments given in the proof of proposition 2. The θ_H-worker exerts the minimal signaling effort e_H^S. I show below that in the absence of investments, the condition $\hat{w}_1 \leq \bar{w}_1$ is more likely to hold. With the investment technology, using (A4) in (A3) as $\hat{w}_1 \to \bar{w}_1$, the condition $\hat{w}_1 \leq \bar{w}_1$ requires that the right-hand side of (A3) not exceed one, by strict concavity of $\phi(\cdot)$. That is,[11]

$$1 \geq \frac{\partial \phi(\beta(2\pi - 1)(\theta_H - \theta_L))}{\partial d}. \quad (A5)$$

Without the investment technology, the corresponding condition, as $w_1^S \to \bar{w}_1 = w_R$, is $1 \geq \partial \phi(\beta \pi (\theta_H - \theta_L))/\partial d$ as stated in (16). Note that $\phi(\beta \pi (\theta_H - \theta_L)) > \phi(\beta(2\pi - 1)(\theta_H - \theta_L))$ for all $\pi < 1$ because $\phi(\cdot)$ is increasing, which implies

$$\frac{\partial \phi(\beta \pi (\theta_H - \theta_L))}{\partial d} < \frac{\partial \phi(\beta(2\pi - 1)(\theta_H - \theta_L))}{\partial d} \geq 1$$

[11] The investment strategy does not appear in (A5). This is a pure consequence of the fact that under proportional solutions to the bargaining problem, the incumbent θ_H-worker and a θ_L-worker who may penetrate into the relationship are investing the same $\hat{y}_{Wi}$. As $\hat{w}_1 \to \bar{w}_1$, the expression of the efficient screening constraint in (A5) simplifies considerably.

by strict concavity of $\phi(\cdot)$. It follows that (A5) implies (16).   Q.E.D.

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