Delegated Job Design*

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April 22, 2003

Abstract

Why do firms delegate job design decisions to workers, and what are the implications of such delegation? We develop a private-information based theory of delegation, where delegation enables high-ability workers to signal their ability by choosing difficult tasks. Such signaling provides a more efficient allocation of talent inside the firm, but at the cost that low ability workers must be compensated to be willing to self-sort. Career concerns put a limit to the efficiency of delegation: when market observability of job content is high, the compensation needed to get low ability workers to self-sort is high, and firms limit delegation to avoid cream-skimming of the high-ability workers. We investigate implications of the theory for how misallocation of talent within firms may occur and to the design optimal incentive contracts.

Keywords: Career concerns, Delegation, Discretion, Peter Principle, Sun Hydraulics.

JEL#: C72, D23, D44, D82, J33, M12.

*We thank numerous seminar participants, and in particular Bengt Holmström, Eirik G. Kristiansen, Ed Lazear, David de Meza, Trond Olsen, Dagfinn Rime, and Michael Waldman for discussions and comments to earlier versions of the paper. The usual disclaimer applies.

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1 Introduction

The traditional method of job design, as evidenced by hiring procedures in government bureaucracies, is to first define the tasks contained in the job slots and then to hire suitable workers (or to reallocate existing workers) to fill those slots, giving workers limited discretion in designing their job. In recent years, this bureaucratic, top-down, solution to the job design problem has been challenged. For example, as described by Baron & Kreps (1999), the engineering company Sun Hydraulics gives employees “the right and responsibility to choose how they spend their time,” and Gore & Ass., the producer of Gore-Tex© products, encourages “maximum freedom for each employee.” While these two examples are extreme, that the delegated job design practices of Sun and Gore are part of mainstream managerial thinking is evidenced by a burgeoning empirical literature (e.g., Caroli et al., 2001, Lindbeck & Snower, 1996, 2000, 2001, OECD 1999, and Rajan & Wulf, 2003). This literature documents the widespread use of practices such as job rotation, matrices, and self-monitoring groups, which all may be seen as increased delegation and flexibility used by firms when designing jobs.[1] Reasonably, however, most firms lie somewhere in between government bureaucracies and Sun Hydraulics, in that workers have some, but not complete, discretion over their field of work.

Why do firms delegate job design to workers? Why do different firms or industries practice different degrees of delegation? Several aspects may be relevant. For example, delegation may act as a commitment device or reduce managerial overload. Or workers may simply enjoy the freedom implied by delegation and be willing to take a pay cut to obtain it, as may be the case in academics.

While these issues may be important, we wish here to develop a simple theory of delegation with worker private information and career concerns as the key ingredients. To motivate our theory, workers may have private information about whether they are creative or not, a characteristic that is notoriously difficult to capture with for example

[1] For example, Caroli et al. (2001) states: ’With more decentralized firms and more small businesses the organizational picture of western economies is changing. This is to be contrasted with the previously dominant scheme, based on a Taylorist tradition, which emphasized the advantage of setting precise norms and closely monitoring workers through their specialization in conception and execution activities.’ (p. 482).

personality tests, or workers may simply have a better knowledge of customer tastes than the manager. Career concerns mean that the job design decision today affects a worker's welfare tomorrow. For example, if the most able workers in a hi-tech firm are engaged in product development, then low ability workers engaged in product development may have better future prospects than low ability workers engaged in product updating, since the market may (correctly) view job description as an indicator of ability.

The basic tension we focus on stems from these two effects of private information. On one hand, private information favors delegation since workers are better equipped to know what they should do. On the other hand, private information means that workers may have incentives to engage in wasteful signaling activities under delegation. For example, less able workers may engage in product development not because it maximizes the firm's profit, but to herd in with the high ability workers.

How much should firms delegate given these effects from private information? To anticipate, the main costs from delegation are that low ability workers need to be compensated to self-sort efficiently, that is to choose tasks with low returns to ability. When the market visibility of task choices are low, an internal labor market emerges where a firm sets a small premium for such tasks and has a high degree of delegation. However, when the visibility is high, the required premium to low ability workers under delegation becomes high. As a consequence, outside firms can cream-skim the high ability workers, and a high degree of delegation would be unprofitable. To avoid the cream-skimming problem, the firm needs to reduce the premium necessary to compensate the low workers to self-sort. The firm obtains this by reducing the career concerns through limiting delegation and instead assigning workers to tasks.

To concretely phrase these ideas and trace their implications, we build upon a simple version of the classic Roy (1951) model. Workers are of two possible ability levels, and there are two tasks, the "easy" task and the "difficult" task. An efficient allocation of workers occurs when the low ability workers specialize in the easy task, and the high ability workers specialize in the difficult task. By job design we mean the decision about which task a worker should specialize in. There are two periods. In the first period, firms offer one-period contracts to the workers, which specify degree of delegation and pay for the different tasks, and workers choose which firm to work for. Before the second period, the firms make offers simultaneously to each worker conditional on their knowledge about ability, and workers accept the highest offer.

Let us summarize the main results. First, there are two types of equilibria which may occur: separating and rationing. In a separating equilibrium, the firm fully delegates the job design decision to workers, and a compensation scheme is structured such that workers do so efficiently. Such a scheme involves paying the low ability workers a premium to self-sort. The high-delegation equilibrium resembles play in companies such as Sun Hydraulics and Gore & Ass., in that job design to a large extent is decided by the employees rather than by the managers. When a separating equilibrium does not exist due to the threat of cream-skimming, there exist a rationing equilibrium. In a rationing equilibrium, only a fraction of employees (which may be equal to zero and hence encompasses pooling) are delegated the job design decision, and the remaining fraction of employees have their jobs defined by the manager. A rationing equilibrium with a high degree of assignment resembles play in bureaucracies, with little or no delegation, while a rationing equilibrium with a moderate degree of assignment resembles typical firms, where only a fraction of workers are delegated the job design, for example through trainee programs or work matrices. Which equilibrium occurs depends on the market observability of the task choices (or wages) of individual workers.

Second, the limits to delegation in rationing equilibria implies that workers' private information is not used efficiently, and a misallocation of workers therefore occurs in equilibrium. One may think that the greatest source of misallocation arising from assignment would be able workers that are not permitted to work in the difficult task. It turns out, however, that the inefficiency invoked by optimal behavior of firms in our model is the opposite: low workers are assigned to the difficult task. This result accords with the Peter principle,[2] in that the prime source of misallocation occurs due to workers being allocated to tasks above their competence level (rather than the source of misallocation being that able workers are occupied below their competence level).

Third, given the concerns that a high degree of delegation can make job design a

[2]The Peter's principle (Peter & Hull, 1969) states that in a hierarcy, employees are promoted to their incompetence level. Recent papers that discuss the Peter's principle includes Fairburn & Malcolmson (2001) and Lazear (2001).

(wasteful) signaling activity, one would expect that the degree of delegation and the degree of misallocation of labor input would be positively related. However, when taking into account the contractual response by firms to the signaling motive, that is in equilibrium, we find that more delegation is associated with *less* misallocation. Hence while it may be true that more delegation leads to more misallocation for a given firm at the margin, the hypothesis we somewhat informally obtain for a cross-section of firms is that firms with more delegation have a lower degree of misallocation.

The job design literature, Holmstrom & Milgrom (1991), Prendergast (1999), and Olsen & Torsvik (2000), among others, considers which combination of tasks should be included in the description of a job, where monitoring and production technology are prime determinants, and how to give incentives such that workers undertake those tasks. There are two main differences between this literature and the current paper. There is a technological difference in that we consider a case where the difficulty lies in having the workers specialize efficiently. More importantly, due to lack of worker private information, previous models have no notion of attempting to draw on worker's competence in designing jobs.

The assignment literature, which includes Rosen (1982) and Gibbons & Waldman (1999a), considers how firms should allocate workers to tasks. However this literature considers settings where workers and firms have symmetric information at the hiring stage, circumstances under which there would be no advantage of delegating the task choice decision. The same point applies to the literature on career concerns, as in Holmstrom (1982/1999).

The delegation literature, which spans areas in political economy, monetary economics, industrial organization, and economics of organization, has emphasized other motivations of delegation than private information, such as delegation as a commitment device (Fershtman and Judd, 1986), reducing managerial overload (Milgrom & Roberts, 1992), costly writing of contracts (Marschak & Reichelstein, 1998), or that workers may have private benefits from delegation which induces harder work (Aghion & Tirole, 1997). Prendergast (2002) considers the interaction between delegation and incentive contracts in a setup related to ours, where worker private information may justify delegation. Prendergast setting is static, and the principal puts limits to delegation because she may be well-informed about which project the worker should attend to. There are no career concerns which induces signaling motives, and hence puts limits to delegation.[3]

The paper has the following structure. In Section 2, we construct the model, and Section 3 presents the main results. Section 4 applies the results to discuss misallocation of talent within firms and some empirical implications. Section 5 extends the model to allow for performance contracts, and Section 6 concludes. The proofs are in Appendix A and in Appendix B.

2 The basic model

Here we first describe the technology and contracts of the model, and then the timing.

2.1 Technology and contracts

There is a continuum of workers and several firms, for simplicity taken to equal two. Each worker privately knows whether he has either low or high ability, while only the share of high ability workers, $\theta \in (0, 1)$, is publicly known.[4] In each firm, there are two tasks; the "easy task" and the "difficult task", denoted by E and D. Both workers have the same productivity in the E task, π^0. In the D task, however, the low type has productivity π^L, and the high type has productivity π^H. We confine attention to the case where it is efficient that high workers are allocated to task D and that low workers are allocated to task E, that is when $\pi^L < \pi^0 < \pi^H$. In our basic setup, we assume that measures of performance is sufficiently noisy to preclude the use of individual or group performance contracts. Contract offers must then simply consist of one wage for the D task, one wage for the E task, and the degree of delegation.[5] In Section 5, we extend the our analysis to

[3]Other papers which include private information as an ingredient in the delegation choice includes Laffont & Martimort (1998), which focuses on costs of communication and collusion between agents, and Faure-Grimaud et al. (2002) which considers the equivalence of centralization and delegation in a setting that builds on Laffont & Martimort (1998).

[4]Foster & Rosenzweig (1996) considers the allocation of workers to different tasks within an agricultural market in Philippines, and find evidence that asymmetric information is present.

[5]It may seem odd that an offer by a firm is a vector of wages, rather than just a wage. However, we can interpret the vector as reflecting differences in overtime payment or fringe benefits between the two

allow for individual performance contracts.

All workers and firms are risk neutral, and for simplicity have discount factors equal to one. Furthermore, we assume that if the wage offers are such that a worker is indifferent between doing the E task or the D task (taking into account the implicit incentives) and he is delegated the choice, then he will choose the efficient task. This may be due to an (unmodeled) option plan or ownership share, or alternatively due to increased job satisfaction in the efficient task. The equilibria we construct will use this tie-breaking rule quite extensively, since both low and high type workers will be indifferent between the wage contracts offered, and one may therefore suspect that the results obtained are knife-edge cases. The robustness of our results are discussed in Section 5 (performance contracts), where indifference only holds for the low type.

2.2 Timing

In the first period, workers are born knowing their ability level, while firms compete in attracting workers. Firms are only able to commit to contracts lasting one period. A firm offers workers w_1^D for the D task and w_1^E for the E task, and the degree of delegation, d. The variable d may alternatively be viewed as the probability of a worker given full delegation once inside the firm, or the probability of a given worker being offered a full-delegation contract. Given the offers, workers choose for which firm to work. Before workers engage in a task, a firm has the option to *raise* any of the wages $\{w_1^D, w_1^E\}$ offered, and allow workers to switch tasks. In other words, firms can commit to not lowering wages, but may choose to raise one of them. This is a natural requirement, because both the firm and workers would (weakly) prefer such a reneged contract.[6] Although such wage raises do not occur in equilibrium, it will turn out to have an impact on equilibrium, through affecting which $\{w_1^D, w_1^E\}$ combinations that can credibly be offered. Workers are then either assigned to a task or delegated the choice, and finally production takes place.[7]

possible tasks.

[6] In technical terms, we are imposing the criterion of renegotiation-proofness.

[7] An alternative, and perhaps more realistic, timing is when workers choose the contract w_1^D or the contract w_1^E (subject to rationing), but are given the option to change slots after entering the firm, and after the firm has had the opportunity to revise w_1^D or w_1^E upwards. This timing of events is equivalent

After the first period, the firms bid for the workers. The *inside firm* (a worker's first period employer) is assumed to be fully informed about the task a worker was engaged in. The *outside firm* (the competitor of a worker's first period employer), however, receives some private, imprecise, signal about it. Given their information, the inside firm and the outside firm compete for the workers before the second period. We assume that the bidding follows a first-price sealed-bid auction; each firm gives an offer to a worker, in ignorance of the other firm's offer, and the worker accepts the highest offer.

We model the outside firm's information, which is private, about task choice (or wage) of a worker in the first period as an independent realization of a random variable X. This X can take two values, E and D. If the worker is in task D, then $X = D$ with probability $p \in [0, 1]$, and $X = E$ occurs with probability $1 - p$, where a larger p means that the signal is more precise. If the worker is in task E, we assume that $X = E$ with probability 1. This assumption is made purely for convenience. In fact, our results are robust to a variety of ways to model the auction.[8] The signal precision, or outside visibility, p is common knowledge, and when $p = 1$ the inside firm and the outside firm are symmetrically informed. To fix ideas, we can think of the signal precision p, which is exogenous, as determined by the extent to which job titles and salaries are precise or diffuse. In this respect, Sun Hydraulics lies at one end of the spectrum by not having job titles for its employees, and a very covert pay policy, while bureaucracies, with well-defined job titles, job descriptions, and salary ladders, being at the other end.

The first-price sealed-bid auction for each worker that goes on between the two periods is realistic for situations where firms may bid in turn, but where workers have no way of

to the one considered.

[8] The reason why we make this assumption is to ensure that the outside firm makes zero profits, which makes the analytical solution to the auction simpler. Our results are robust to letting the private signal structure being symmetric, and to the information received by the outside firm being public. Other papers, e.g., Greenwald (1986) and Acemoglu & Pischke (1998), model the competition for workers as a sequential auction where the inside firm can always match the offer made from the outside firm. Since it is not obvious what the actual 'rules' of bidding games in labor markets are, we should emphasize that our modeling choice is one of convenience; any bidding setup where Remark 1, part ii), holds would work, which would be the case e.g., in certain hybrid versions of first-price auctions and the auction considered by Greenwald (1986).

verifying the offer made by one firm to the other firm. Hence firms make secret or unverifiable offers to workers, so that a worker cannot start a "bidding war" by documenting an offer from the other firm.[9]

3 Results

We first present results that focus on *separating equilibria*, where $d = 1$ and both types of employees work on their appropriate task in period 1. We then examine *rationing equilibria*, where $d < 1$ and (a fraction of) employees are working on a wrong task in period 1. Notice that there is no incentive for worker misrepresentation in the second period, hence inefficiencies, if they occur, do so in the first period.[10]

3.1 Separating equilibria

To study separating equilibria, we start out by analyzing equilibrium bidding for workers in the second stage, given that a separating equilibrium is played in the first stage. Recall that when the sorting is efficient at time 1, the inside firm knows the ability of a worker before the second period, while the outside firm receives a noisy private signal about the task choice (or wage) of a worker in the first period. Let w_2^E and w_2^D denote the expected second-period wage (that is the expected maximum offer) of a worker that chose task E and D, respectively, in the first period.

Remark 1 *Given that a separating equilibrium is played,*

(i) $\pi^0 \leq w_2^E < w_2^D \leq \pi^H$*, with strict inequalities for* $p < 1$*.*

(ii) $w_2^D - w_2^E$ *increases in* p*.*

Proof. See Appendix A. ■

[9] The bidding setup ensures that there will be positive a turnover rate between the two periods (and a higher turnover rate for low workers). Hence there will be a lemons problem in equilibrium, but not to the extent that trade breaks down. The sequential bidding structure of Greenwald (1986) is unable to explain equilibrium turnover without assuming 'utility shocks', i.e., an urge to change employer even if the inside firm offers a higher wage, in contrast to our approach.

[10] The model can easily be extended to cover an arbitrary number of periods, in which case there can be inefficiencies in all periods except the last one.

Remark 1 gives the essential properties of the mixed-strategy Nash Equilibrium of the bidding game between the inside firm and the outside firm, where the inside firm bids conditional on the true type of each worker (since ability is revealed to the inside firm in a separating equilibrium), and the outside firm bids conditional on the signal X. The intuition for part (i) is that a worker that chooses the difficult task in the first period enjoys better career prospects than a worker that chooses the easy task in the first period, since the outside firm (partially) learns the ability of the worker. Due to the inferior career prospects, a worker that chooses the easy task in the first period must hence be compensated. The intuition for part (ii) is that a more informative signal means that more is learned by the outside firm about the ability type of a worker before the second period, and there will be a more intense competition for a worker that choose the difficult task in the first period. Hence the wage difference in the second period increases in the degree of outside observability of task choice in the first period.[11]

In fact, property (ii) of Remark 1 is the main building block to our results. To anticipate, the immediate implication of part (ii) is that a firm must pay low ability workers a higher wage in the first period to be willing to sort, the higher p. This in turn makes the threat of cream-skimming, by offering a low wage for the easy task, stronger, and a separating equilibrium is thus less prone to exist the higher p. To avoid the wage difference between low and high ability workers becoming too high in period 2, and cream-skimming occurring in the first period, a firm rations the slots in one of the task, and we get an equilibrium where the firm designs the job for some workers.

The following proposition describes the contracts and wage setting in separating equilibria. The proof is in Appendix A.

Proposition 1 *A separating equilibrium has the following properties:*

(i) The job design is fully delegated to workers, and workers separate efficiently.

(ii) Low (high) workers get a wage that is higher (lower) than their marginal produc-

[11] When $p = 1$, wages in the second period will equal marginal productivity, i.e., $w_2^E = \pi^0$ and $w_2^D = \pi^H$. When $p = 0$, the high workers also receive a higher wage than the low worker in the second period. In this case, the outside firm must bid equally aggressive for both type of workers. The inside firm, however, bids more aggressively for the high workers than for the low workers, since the former has a higher value to the firm.

tivity in both periods.

(iii) High workers have a steeper wage profile than low workers across the two periods.

In a separating equilibrium, the firm sets no limit to entry in any of the tasks, and we can interpret this equilibrium as a situation where workers are hired and then fully delegated the job design choice.[12] To be willing to signal low ability by choosing the easy task, low workers must be compensated by a relatively high wage in the first period. This implies that the wage profile of high workers is steeper than the wage profile of the low workers, since ability is partially revealed in the market.

A separating equilibrium identifies the advantages of delegation in this economy. If firms instead of delegating the job design decisions to workers assigned the workers randomly, they would obtain an expected production of $\theta\frac{\pi_H+\pi_0}{2}+(1-\theta)\frac{\pi_L+\pi_0}{2}$. On the other hand, the average production in separating equilibria equals $\theta\pi_H+(1-\theta)\pi_0$. The extra production (and wages) in separating equilibria increases in θ. Furthermore, separating equilibria are "fair", in that the lifetime utility of low and high workers are equal. This follows from the fact that $w_1^E+w_2^E=w_1^D+w_2^D$ must hold for workers to sort into their efficient task in the first period. Notice that this expression hides a double indifference condition, in that both low and high workers must be money-wise indifferent in a separating equilibrium. In Section 5, we show that this property will vanish if firms have access to a contractible measure of individual performance, in which case indifference will hold only for one of the types, and the high-ability type will make strictly more than the low ability type in equilibrium.

We now explain the conditions for existence of a full delegation, separating, equilibrium.

Remark 2 *(i)A separating equilibrium is more likely to exist for lower p. (ii)Furthermore, a separating equilibrium always exists for $p=0$.*

[12] Instead of delegating the job design choice, a separating equilibrium could be implemented by workers reporting their type and the principal assigning workers. However, low ability workers might fear that the firm would use the report against them, through various measures of discrimination, and delegation may be a cheap way for the firm to commit to not exploiting the information. Another reason for strictly prefering delegation could be costs of communication.

Proof. See Appendix A. ■

In a separating equilibrium, firms pay low workers a premium above their marginal productivity in the first period, to make such workers self-sort. This creates a potential incentive for firms to deviate in order to attract only high workers, by holding the offer w_1^D fixed and reducing w_1^E. However, when it is sufficiently inexpensive for firms to make low workers choose the easy task instead of the difficult task, once workers have entered the firm, by raising the offer w_1^E at that point, such cream-skimming is not credible, and a separating equilibrium exists. When the signal precision is low, $w_2^D - w_2^E$ is low, and it is cheap to revise the offer w_1^E upwards to make low workers choose the easy rather than the difficult task. Hence when p is low, cream-skimming cannot be credible and a separating equilibrium exists. On the other hand, when the signal precision p is high, $w_2^D - w_2^E$ is high, and it is expensive to revise the offer w_1^E upwards to make low workers switch from the difficult to the easy task. Hence a separating equilibrium is less likely to exist the higher signal precision p.

Since the full delegation in a separating equilibrium differs radically in spirit from the assignment and job design literatures, where firms direct workers to do specific tasks rather than delegating the choice, let us pause to discuss the plausibility of separating equilibria in light of documented management practices.

That high-delegation practices are common on a wide basis is indicated by the pioneering study of Osterman (1994), which reports on the degree of employee discretion in 875 US companies (with 50+ employees). Osterman finds that 45% of employees have complete or large discretion over the choice of work method.[13] More concretely, Baron & Kreps (1999) reports on the management practices of Sun Hydraulics Corp., a company founded in 1970 to manufacture fluid power products. Sun deemed standard management tools such as organization charts to be destructive, by restricting employee initiative and information. To deal with such problems, Sun designed the organization to eschew with almost all forms of hierarchy. As Baron & Kreps (1999), p. 87, put it : 'Work [at Sun] is self-organized. [..] Individual workers retain the right and responsibility to choose how

[13] Delegation over work method and delegation in job design are conceptually two separate issues, but it does not seem implausible to conjecture that they are empirically closely related.

they spend their own time.[14] In 1997, Sun's products apparently enjoyed a higher margin than competitors, and had a reputation for outstanding quality.[15] Separating equilibria fit to several features of Sun. In particular, Sun is – in addition to having a high degree of delegation – characterized by low degree of outside observability. For example, job titles being non-existent at Sun (Baron & Kreps, 1999, p. 295), it is hard for outside firms to assess the allocation of individual employees. Perhaps not surprisingly, the pay levels of individual workers is also very covert information in these firms.

A substantial amount of empirical work has shown that worker (nominal) wages and wage dispersion typically increase over time (see Gibbons & Waldman, 1999b, for an excellent overview of the careers in organization literature). In an older version of the paper, we showed that separating equilibria have these properties given that we accommodate a degree of human capital acquisition between the two periods and that the effort cost (e.g., hours on the job) is higher for completing the difficult task than the easy task.[16]

A large theoretical and empirical literature builds on Akerlof (1970) to consider adverse selection in the labor market (e.g., Greenwald, 1986, Foster & Rosenzweig (1996), and Acemoglu & Pischke 1998), which occurs when workers know more about their abilities than firms do. This literature implicitly assumes that the workers ability is revealed to the firm once hired. In our model, in contrast, adverse selection may occur when workers allocate inside the firm, in addition to at the hiring stage. Hence firms in our setting face *two* adverse selection problems. To illustrate that point, suppose a firm simply decided not to assign the workers - and set equal wages for the two tasks. In that case, low-quality

[14] The degree of discretion given to workers at Sun can be illustrated by a case where an engineer had been hired with a product development function in mind but had 'become intrigued with the computer in his first days on the job, and since had concentrated entirely on creating new programming applications.' (Kaftan, 1984).

[15] The following statement from W. L. Gore, founder of Gore & Associates, is an echo from Sun: 'In Gore & Ass., one of our basic principles is to encourage maximum freedom for each employee. There is no need for bosses, assignment of tasks, establishing lines of command, defining channels of permitted communication, and the like' (Gore, 1990).

[16] These properties also make separating equilibria consistent with the low ability workers making lower wages than high ability workers in both periods. Briefly, human capital acquisition will ensure that the wage profile of both types of workers are increasing, and extra hours required to finish the difficult task ensures that the high ability workers will earn more in both periods.

workers would imitate high-quality workers and herd into the more prestigious task (to obtain a higher future compensation), and there would be harmful adverse selection of workers within the firm.

3.2 Rationing equilibria

We now consider the delegation policy of a firm when the degree of outside observability is high, and a separating equilibrium consequently does not exist.

Proposition 2 *(i) When a separating equilibrium does not exist, there exists a rationing equilibrium, where only a fraction of workers are delegated the job design decision, and the remaining fraction of workers is assigned to the difficult task.*

(ii) There does not exist a rationing equilibrium where any workers are assigned to the easy task.

(iii) The fraction of workers that are assigned increases in the signal precision p.

Proof. See Appendix B. ■

When the degree of outside observability is high, full delegation implies that the wage difference $w_2^D - w_2^E$ would be high, the low workers would thus require a high wage in the first period to separate, and credible cream-skimming by the other firm would make full delegation unprofitable. To avoid cream-skimming, a firm therefore assigns (some) workers to tasks, and hence reduces the compensation required by the low workers that self-sort to the easy task.[17]

The intuition for why there cannot be a rationing equilibrium where the number of slots in the difficult task is that if the D slots were rationed, firms could increase productivity without increasing the costs of compensation, by letting more (high) workers do the difficult task.[18]

[17] An alternative interpretation of rationing equilibria is that of job rotation; all interested workers are allowed to do the easy task, but only a certain amount of time.

[18] If the production technology were such that the simple task must be done (as with the product catalogue of Sun Hydraulics), a high degree of rationing in equilibrium implies that separate workers, without the option to switch to the difficult task, must be hired to do the easy task.

The degree of rationing in a rationing equilibrium is determined by the degree of outside observability, p. A higher p implies a higher degree of rationing, and when $p = 1$, that is symmetric information between the inside and the outside firm, there can exist *pooling equilibria* where all workers are assigned. Hence rationing equilibria capture both firms with a low degree of delegation, as in government bureaucracies, and more typical firms, where a certain fraction of employees are delegated the choice of specialization.

It is somewhat surprising that rationing takes the form of assignment to the difficult task, not to the easy task. We can add plausibility to this result by considering an example. A frequent complaint about bureaucracies is that too many persons are employed in middle-level management positions, rather than working on more customer-oriented, clerical tasks (the Peter principle). We can interpret management as the difficult task and the clerical task as the easy task. Our results then provide an argument for why there are too many employees at the management level: a more efficient allocation would make it too easy for outside firms to cream-skim high-quality employees.

In the extension of that point, observe that the argument behind rationing equilibria can provide a limit to the effectiveness of organizational reforms in the public sector, an issue continuously debated in many countries. In the short run, public sector bureaucracies might be able to keep the same level of production by downsizing and delegating more to the retained workers. However, such a policy would induce low future wages for those that reveal themselves as having lower ability, and to compensate these workers their current wage would have to be raised. This, in turn would create incentives for outside (perhaps private) firms to cream-skim, by offering worse conditions for low ability workers than the public sector would do. In the longer run this process could lead to the public sector being be drained of its talent, in that the fraction of low ability workers, paid above their marginal product, would become high. Hence a certain amount of misallocation in the public sector can be desirable.

What would happen if workers learn about the match with particular tasks only after entering a firm, but before choosing tasks? In that case, there would be no adverse selection at the hiring stage, since cream-skimming is not a viable strategy, and a higher wage gap would be sustainable in equilibrium. Thus workers learning about the match with tasks after they enter the firm would support more delegation. This argument might be relevant for explaining why consulting firms hiring workers at the bottom level often give such workers, after an initial general training, a relatively high degree of discretion in deciding which industries to specialize in. The same type of argument might apply to stock market analysts picking which stocks to cover.

4 Misallocation of talent

We have provided a theory of job design, that in a tractable manner accommodates the delegation of hi-tech firms such as Sun Hydraulics, and of (government) bureaucracies, delegating job design only to a small degree, and practices in between. We now wish to analyze the implications of this theory for the issue of misallocation of talent within firms, and to discuss the empirical relevance of our theory.

Let us define the misallocation of a worker as the difference between his productivity in equilibrium and that under a full information equilibrium. Then we have the following.

Proposition 3 *(i)Misallocation of workers can occur in equilibrium, and is lower the higher degree of delegation. (ii)Misallocation occurs due to low ability workers performing the difficult task.*

Proof. Follows directly from Proposition 2. ■

In a one-period problem allocation problem, firms would simply pay an equal wage for the two tasks, and fully delegate the job design decision to workers, and an efficient allocation of workers would follow. The reason why misallocation takes place in our two-period economy is that a firm realizes that by delegating too much, it would suffer from adverse selection, in that the competing firm would be able to cream-skim the most able workers.

On the form of misallocation we find, too many workers perform the difficult task in low-delegation firms. In principle, firms could improve productivity by inducing (low ability) workers to move from the difficult task to the easy task, but the necessary compensation to a worker for the career damage of being identified as a low worker would exceed the gain in productivity from the movement.

A natural question is what hypothesis we can derive on misallocation within firms for a cross-section of firms from different industries, where the firms in each industry have the same p, but where p differ between industries. For example, public sector units normally have job titles (and individual salaries) that are on a clear-defined ladder, and are hence relatively informative about the type of work individuals do. Part of the reason for this is probably that coordination costs from having obscure job titles may be high in a larger organizations, but equally important there will be political regulations promoting transparency, to make the bureaucracy accountable to the politicians (and voters). On the other hand, we envisage industries like hi-tech, with less-defined ladders and job titles, and often managers with a substantial ownership share so that accountability is less of a problem, to have a lower p.

Proposition 4 *For a cross-section of firms, (i)The degree of misallocation and the degree of delegation are negatively related, and (ii)The wage levels and the degree of delegation are positively related.*

Proof. Follows directly from Proposition 2. ■

Since increased outside observability gives less delegation and more misallocation, for a cross-section of firms from different industries, the degree of misallocation and the degree of delegation are inversely related in equilibrium. From this result, we expect a higher degree of misallocation of workers in industries with a high degree of outside observability, such as in the public sector, than in industries with a lower outside observability, such as hi-tech. Furthermore, since more delegation is associated with a more efficient allocation of workers, we also expect wages to be higher in industries or firms with higher delegation.

Cross-sectional data on delegation presently being scarce, it is difficult to firmly assess the empirical validity of these hypotheses. One indirect way of testing the first hypothesis can be based on differences in mobility costs. For example, older (or married) workers can be expected to have higher moving costs than younger (or unmarried) workers. This should make firms less anxious about older workers being bid away, and hence we can expect a higher degree of delegation for older workers than for younger workers. This type of reasoning might provide an explanation for programs where employees close to retirement are given more freedom than younger employees. Also, this line of argument may explain the finding of Rajan & Wulf (2003), who considers pay and organizational structure of 300 large US firms, that companies with more long-term compensation (stocks, options), which can create mobility costs since such payments are usually conditional on some extent of "loyalty", delegate more to lower level managers.[19]

Moving to the second part of Proposition 4, Rajan & Wulf (2003) do not find conclusive evidence on the relation between pay levels and degree of delegation (decentralization) for their cross-section of firms, in contrast to what we predict. General equilibrium effects might explain this lack of (or weak) support. Since wages will be higher in industries with lower p (i.e., lower transparency), we would expect an inflow of workers into these industries from workers in high-p industries. In the current setting, firms operate under constant returns to scale, which means that a low-p/high wage sector can absorb all the workers in the economy without wages becoming lower. More realistically, there can be demand side effects market from workers migrating into a sector, driving wages down, which can partially explain the lack of support of our hypothesis. Notice, however, that even with migration of workers, it would still be the case that the low-p industries would have a higher degree of delegation and a lower degree of misallocation than high-p industries.

Obviously, if a firm could choose its p freely and without costs, it would maximize profits by choosing it as low as possible, both to avoid cream-skimming and to obtain an informational advantage over other firms. One reason for why p is not easily manipulable, and different across firms (and industries), could be that it is shaped by company culture (the degree of openness), which is slow to change. A more tangible difficulty with lowering visibility could be that low visibility firms would run into problems with recruiting employees with the highest potential for learning, since such employees would tend to prefer to work for firms where their learning potential will later be revealed to the market. Another cost of lowering visibility could be increased coordination costs inside the firm, due to for example the duplication of work, since decreasing visibility from the outside would probably mean making the organization less transparent also for insiders.[20] This

[19] Or maybe a firm needs to create performance incentives if it wishes to delegate, and the use of stocks/options is a response to that need. This argument is consistent with the analysis in the next section.

[20] Herbold (2002) gives a vivid description of the coordination problems that occured due to too much delegation at Microsoft.

argument may partially explain why industries dominated by small start-ups, as segments of the software industry, seemingly have a high degree of delegation: the (incremental) coordination costs from having diffuse job descriptions are small. The reverse argument may explain why larger firms seemingly have more precise job descriptions and a lesser degree of delegation.[21]

In sum, given the shortage of systematic data beyond case studies on the extent and effects of delegation and job design practices of firms, we do not have a sufficient basis for a clear verdict on the empirical importance of the effects we have focused on. However, given the ongoing efforts to generate data in this area, our attempt to establish some benchmark relations between (degree of) delegation and other variables such as wages and the degree misallocation, seems useful.

5 Performance contracts

To amplify our points, we have made some strong assumptions. In particular, we have considered a case where firms have no way of separating workers other than offering a schedule that makes both worker types indifferent between which task to choose. What if other instruments of sorting workers than delegation were available to the firm? In this section we consider the case where contracts based on individual performance in the first period are feasible (the analysis with performance contracts being possible in both periods gives qualitatively the same results, but with more notation). The main results of the section show that our insights are *strengthened* by the introduction of (noisy) measures of individual performance, in that we obtain equilibria with the same qualitative features

[21] Osterman (1994) gives some support to this hypothesis. A related hypothesis relates delegation to ownership structure. For a publicly held firm with a dispersed ownership structure to be accountable to shareholders, the shareholders need to have access to the operations of the firm, including its personell policy. For a privately held firm there is less need for such outside visibility since the owners are either insiders to the firm, or the number of outside owners is small so that free-riding on information acquisition is a minor problem. From this, we expect publicly held firms to delegate less than privately held firms, and have a higher degree of misallocation. Among the costs of a closer ownership structure is the lesser wealth diversification by owners of privately held firms, so from a security design perspective we can envisage a trade-off between higher productivity and more diversification.

with respect to delegation and premium paid to low ability workers, but where the high type worker strictly prefers the difficult task.[22]

We assume that output in the E task is as before independent of ability, and with mean π_0. Those choosing the E task will therefore be offered a fixed salary F. We furthermore assume that there are two possible outputs in the difficult task, π^{high} and π^{low}, where a low (high) type worker has a probability P_L (P_H) of obtaining the high output, where expected output for the low (high) worker equals π_L (π_H), and $P_L < P_H$. A worker in the D task obtaining the output π_L (π_H) will be paid the first period wage B_L (B_H). To avoid trivial forcing contracts, we assume that workers are risk-neutral, but have limited liability, so that F, B_L, $B_H \geq 0$. To focus on the rationing mechanism, we assume that information about task choice is symmetric between the inside and the inside firm both with respect to task choice ($p = 1$) and with respect to the performance of a worker.[23]

5.1 Separating equilibrium

In a separating equilibrium, abilities are revealed and the second period wage must be π_H for high workers and π_0 for low workers. To induce self-sorting as cheap as possible, optimal contracts must have $B_L = 0$, and we can therefore write B_H simply as B. Denoting the lifetime utility for a type i worker choosing task j for U_i^j, we then have,

$$U_H^D = P_H B + \pi_H \tag{1}$$

The first term is the expected wage in the first period, and the second term is the wage in the second period, for a high worker choosing the D task. On the other hand, the utility for a low worker for choosing the E task equals,

$$U_L^E = F + \pi_0 \tag{2}$$

[22] Performance contracts in the current setting only serves to sort workers. We can easily extend the model to encompass moral hazard problems. Such considerations would induce additional inefficiencies that are not our focus here.

[23] Since workers reveal their type in a separating equilibrium, the conditions for existence of such an equilibrium do not depend upon performance being observable to the outside firm or not. The rationing equilibrium would also have the same qualitative features but slightly different wages.

Where F is the fixed wage in the first period and π_0 is what he gets in the second period. We have two IC conditions for a separating equilibrium,

$$P_H B + \pi_H \geq F + \pi_0 \tag{IC1}$$

$$F + \pi_0 \geq P_L B + \pi_H \tag{IC2}$$

The first equation is the self-sorting constraint for high type workers, and the second equation is the self-sorting constraint for the low type workers.

If $F > \pi_0$, then the second IC condition binds.[24] Assuming $F > \pi_0$, we can determine F as,

$$F = P_L B + \pi_H - \pi_0 \tag{3}$$

$$F = P_L B + \max\{P_L \pi_H / P_h - \pi_0, 0\} \tag{4}$$

This implies (by $P_L < P_H$) that high-ability workers strictly prefer the D task in a separating equilibrium (thus the first IC constraint holds as well).

The zero profit condition is,

$$\theta \pi_H + (1-\theta)\pi_0 = \theta B P_H + (1-\theta)F \tag{5}$$

The left hand side is the expected productivity of the firm, and the right hand side is the total wage bill. The IC2 condition and the zero profit conditions then determine the equilibrium values of F and B, denoted by F^* and B^*, as

$$\begin{aligned} B^* &= \frac{\pi_0 - (1-2\theta)(\pi_H - \pi_0)}{\theta(P_H - P_L) + P_L} \\ F^* &= \frac{\theta(P_H + P_L)(\pi_H - \pi_0) + P_L \pi_0}{\theta(P_H - P_L) + P_L} \end{aligned} \tag{6}$$

To have the same type of separating equilibrium as in the previous sections, where the low type is paid above marginal productivity to self-sort, we need that $F^* > \pi_0$.[25] From (5), this occurs whenever $P_L \pi_H + P_H(\pi_H - 2\pi_0) > 0$. If $P_L \pi_H + P_H(\pi_H - 2\pi_0) < 0$, however,

[24] If not, a firm can offer a contract with a lower F and obtain only the high ability workers. This firm would not have incentive to later raise the low ability worker's wage since such worker would already have incentive to self-sort.

[25] The liability constraint $B^* \geq 0$, is satisfied whenever $\theta > \frac{1}{2} - \pi_0/(\pi_H - \pi_0)$. Hence θ low is an additional reason to get rationing, but let us assume that θ is sufficiently high in the following.

we get $F^* < \pi_0$ from (5), which clearly cannot occur in (separating) equilibrium, since a firm would make a profit no matter who shows up in the E task. In that case, there exists a separating equilibrium with $F^* = \pi_0$ and $B^* = \pi_H/P_H$, or in other words that both type of workers get (expected) wage equal to marginal productivity in both periods, which is a qualitatively different separating equilibrium from that obtained previously.[26] To single out further conditions for existence of a separating equilibrium where low workers are paid a premium to self-sort, we now consider the possibility of cream-skimming.

Suppose one of the firms deviates by offering a low wage for the easy task (i.e., an attempt to cream-skim). This firm will have incentives to renegotiate this offer after workers have chosen which firm to work for, by raising the wage for the easy task such that $w_1^E = F$, if the production gain exceeds the wage compensation loss. The extra compensation needed to induce a low ability worker to switch tasks equals to $\pi_H - \pi_0$, that is the wage loss in period 2 from being revealed as having low ability. It will pay to make this compensation only if the productivity improvement exceeds the extra compensation, or in other words if

$$\pi_0 - \pi_L \geq \pi_H - \pi_0 \tag{7}$$

When this no cream-skimming condition holds, a separating equilibrium exists, which is completely analogous to the case without performance contracts. By combining the no cream-skimming condition and the condition $P_L\pi_H + P_H(\pi_H - 2\pi_0) > 0$, we see that a separating equilibrium of the type considered in the main text, where the low ability workers are compensated to self-sort, exists whenever $\frac{P_L}{\pi_L} > \frac{P_H}{\pi_H}$. Since this condition always holds for $P_L = P_H$, the essential requirement for this type of separating equilibrium is that the difference $P_H - P_L$ is not too great, or in other words that the monitoring technology is not too precise, which is an intuitively appealing result. Let us summarize.

Proposition 5 *When the no cream-skimming condition (7) holds and the monitoring technology is not too precise, a separating equilibrium exists where the low ability workers are paid above their marginal productivity. When monitoring is precise, a separating equilibrium exists where both workers are paid their marginal productivity. In both types*

[26] This solution will satisfy (IC2) if $2\pi_0 \geq P_L\frac{\pi_H}{P_H} + \pi_H$, which is the same condition that determines when our candidate F^* is less than π_0. Thus, we can get a separating equilibrium for this case.

of separating equilibria, all workers are fully delegated the job design decision, and a high ability worker strictly prefers the difficult task.

Let us now see what happens if the no cream-skimming condition does not hold.

5.2 Rationing equilibrium

In a rationing equilibrium, a worker that chooses the E task in the first period will be of low ability with probability 1, and will therefore get the wage π_0 in the second period. For a worker that chooses the D task, the wage in the second period will depend on the fraction of low workers in the D task and on whether that worker obtained a bonus or not. Recall the assumption that pay can only be conditioned on performance in the first period, and hence that workers simply get their expected productivity conditional on correct sorting in the second period.

Let θ_H (θ_L) be the fraction of workers with a high (low) performance that is of high ability, and let f be the fraction of low ability workers that are assigned to the D task, while a fraction $1-f$ are allowed to choose freely, and hence chooses the E task. Then,

$$\begin{aligned} \theta_H &= \frac{\theta P_H}{\theta P_H + (1-\theta) f P_L} \\ \theta_L &= \frac{\theta(1-P_H)}{\theta(1-P_H) + (1-\theta) f (1-P_L)} \end{aligned} \tag{8}$$

Furthermore let w_2^H (w_2^L) be the second period wage for a worker with a high (low) performance in the first period. Then,

$$\begin{aligned} w_2^H &= \theta_H \pi_H + (1-\theta_H)\pi_0 \\ w_2^L &= \theta_L \pi_H + (1-\theta_L)\pi_0 \end{aligned} \tag{9}$$

Clearly $w_2^H > w_2^L$ since a high ability worker has a better chance of getting a bonus than a low ability worker. We now have the IC conditions for a rationing equilibrium,

$$P_H(B + w_2^H) + (1-P_H) w_2^L \geq F + \pi_0 \tag{IC3}$$

$$F + \pi_0 \geq P_L(B + w_2^H) + (1-P_L) w_2^L \tag{IC4}$$

(IC3) is the self-sorting constraint for high type workers, and (IC4) the self-sorting constraint for the low type workers in a rationing equilibrium. As with a separating equilibrium, if $F > \pi_0$ and (IC4) were not binding, a firm can improve profits by lowering F and getting a smaller fraction of low type workers. Hence we can determine F as,

$$F = P_L(B + w_2^H) + (1 - P_L)w_2^L - \pi_0 \tag{10}$$

Since (IC4) binds, (IC3) becomes redundant (by $P_L < P_H$ and $w_2^L < w_2^H$), and high ability workers must strictly prefer the D task also in a rationing equilibrium.

The zero profit condition is,

$$\theta\pi_H + (1-\theta)(1-f)\pi_0 + (1-\theta)f\pi_L = \theta BP_H + (1-\theta)(1-f)F + (1-\theta)fBP_L. \tag{11}$$

The left hand side is the expected productivity of the firm, and the right hand side is the total wage bill. The first term on the left hand side is the productivity of high ability workers, the second term is the productivity of the low ability workers that choose the E task, and the third term is the productivity of low ability workers that are rationed. The right hand side gives the corresponding wages for those three groups of workers. The third equilibrium condition is that firms should be indifferent between shifting low ability workers (i.e., decreasing f) on the margin,

$$\pi_0 - \pi_L = F - P_L B \tag{12}$$

Again, the productivity improvement from shifting workers is on the left hand side, and the required extra compensation on the right hand side. We now have five endogenous variables, F, B, f, w_2^L, and w_2^H, and five equations, the no-shifting equation, zero profits, the IC2 condition, and the equations determining w_2^L, and w_2^H. This system has a unique solution which equals,

$$\begin{aligned}
B^* &= \frac{\theta(\pi_H - \pi_L) + \pi_L}{\theta(P_H - P_L) + P_L} \\
F^* &= \pi_0 + \frac{\theta(P_L\pi_H - P_H\pi_L)}{\theta(P_H - P_L) + P_L} \\
f^* &= \frac{\theta P_H(P_L(\pi_H - \pi_0) + \pi_L - \pi_0)}{P_L(1-\theta)(P_L(\pi_H - \pi_0) + 2\pi_0 - \pi_H - \pi_L)}
\end{aligned} \tag{13}$$

The degree of rationing f^* can be seen to be increasing in the level of θ, increasing in P_H, and ambiguous to changes in P_L. $F^* > \pi_0$ whenever $\dfrac{P_L}{\pi_L} > \dfrac{P_H}{\pi_H}$, which is the same condition on monitoring as described above.[27] To see that there cannot be rationing in the case of perfect monitoring technology, that is when $P_L = 0$ and $P_H = 1$, observe that the denominator of f^* goes to 0 when P_L approaches zero. By solving for $f^* = 0$, we get that rationing occurs whenever $P_L > \dfrac{\pi_0 - \pi_L}{\pi_H - \pi_0}$, from which it follows that $\pi_H - \pi_0 > \pi_0 - \pi_L$ must hold to get rationing, as shown before. We can then summarize.

Proposition 6 *If a separating equilibrium does not exist, there exists a rationing equilibrium where some workers are assigned to the D task. In such an equilibrium, a low ability worker is paid a premium to be willing to self-sort, and a high ability worker strictly prefers the D task to the E task.*

Hence, the introduction of contractible measures of individual performance strengthens the qualitative insights of the paper in the following sense: With optimal performance contracts, we can still get rationing, a low type worker is paid a premium to be willing to self-sort, and moreover a high type worker strictly prefers the D task to the E task, provided that the monitoring technology is not too precise. In other words our line of argument is not dependent on the double indifference condition in the previous sections, nor on individual performance not being contractible. More generally, if other screening mechanisms are available, but are imperfect due to for example measurement costs, then job design gives information about ability, and we get the interaction of private information and career concern effects that has been our focus.

6 Concluding remarks

Why do firms delegate job design to workers, and what are the implications of such delegation? We have developed a private-information based explanation of delegation, where delegation enables high-ability workers to signal their ability by choosing difficult tasks. Such signaling provides a more efficient allocation of talent inside the firm, but at the cost that low ability workers must be compensated to self-sort. Career concerns put a limit to the efficiency of delegation: when market observability of job content is high,

[27] If $(2\pi_0 - \pi_H)/\pi_H \le P_L/P_H \le \pi_L/\pi_H$, the (IC4) constraint may not be binding and as before we must have $F^* = \pi_0$.

firms limit delegation to avoid cream-skimming of the high-ability workers. Two of the implications of the theory are that the degree of misallocation of talent inside the firm decreases in the degree of delegation, and that misallocation takes the form of too many workers undertaking tasks with a high return to ability, like management, and too few perform "simple" tasks, such as customer service or catalogue revision. This is the same type of inefficiency as implied by the Peter principle. Finally, for a cross-section of firms we expect that firms with more delegation also have a lower degree of misallocation and higher wages.

Let us end the paper with a speculation. A fascinating aspect of organizations is that some seem much more innovative than others. From the limited evidence of Sun Hydraulics and Gore, and more prominent firms such as Microsoft, one gets the impression that free-wheeling organizations with a high degree of delegation innovate more than more traditional, hierarchical organizations. Can there be a link between a firm's degree of delegation and its innovation rate? If so, is there such a link because such organizations recruit the right people, or because the people "become right" after being hired? To discuss such issues in an interesting manner, we believe one would need to confront such factors as learning potential of employees, the ownership/financial structure of the firm, and product market conditions, in addition to factors discussed in the current paper. That is left for future work.

7 Appendix A: Separating equilibrium

Proof of Remark 1. Recall that this is a first price sealed-bid auction where the inside firm bids conditional on the true productivity of the worker, and the outside firm bids conditional on its private signal. There cannot exist a pure strategy auction equilibrium, and we here derive the mixed-strategy equilibrium.[28]

The inside firm uses a mixed strategy with cumulative distribution of F^L for a low worker and F^H for a high worker. Clearly, the inside firm will never bid more than π^0 for a low worker. As can be shown, the inside firm cannot bid below π^0 for a low worker, and F^L must therefore be the distribution degenerate at π^0. Thus the inside firm can

[28] A similar auction was solved by Wilson (1967).

only make a profit on high workers. For F^H, the support of the distribution will be $S_{inside} = [\pi^0, \bar{\pi}]$, where $\bar{\pi} < \pi^H$. The outside firm will, conditional on the realization of the signal being i, use a cumulative bid distribution $G^i(x)$ with support $S^i_{outside}$, where $i \in \{D, E\}$. As can be verified, the outside firm must make zero profits when the signal is E, and bids π^0 for those workers. Consequently, $S^E_{outside} = \{\pi_0\}$ and $S^D_{outside} = S$. Recall that the probability of a high worker receiving the signal realization D equals 1. Given that the inside firm offers x to a high worker, the expected surplus the inside firm makes on that bid equals,

$$(\pi^H - x)G^D(x),\ x \in S, \tag{A1}$$

where $G^D(x)$ is the probability that the inside firm wins the auction for a high worker, and $(\pi^H - x)$ is the surplus if it wins. Since the inside firm plays a mixed strategy when bidding for a high worker, it must be indifferent at all points in its support,

$$(\pi^H - x)G^D(x) = k_{inside},\ x \in S, \tag{A2}$$

where k_{inside} is a constant that equals the surplus the inside firm makes on a high worker. Now define the probability of a worker being high conditional on the signal realization being D as θ^D. Then,

$$\theta^D = \frac{\theta}{\theta + (1-p)(1-\theta)} \tag{A3}$$

Given that the outside firm offers y to a worker with a signal D, the outside firm gets the expected surplus per worker,

$$\theta^D F^H(y)(\pi^H - y) + (1-\theta^D)F^L(\pi^0 - y) = k^D_{outside},\ y \in S. \tag{A4}$$

The first term is the expected surplus when bidding for a high worker, and the second term is the expected loss from bidding for a low worker. By the same argument as for the inside firm, the outside firm must be indifferent at all points in his support. Since $\pi_0 \in S$, the outside firm makes zero profits and $k^D_{outside} = 0$. Furthermore, since F^L is degenerate at π^0 we can rewrite (A4) as,

$$\theta^D F^H(y)(\pi^H - y) + (1-\theta^D)(\pi^0 - y) = 0,\ y \in S. \tag{A5}$$

We can then substitute in for $y = \pi^0$ in (A5) to get

$$F^H(y) = \frac{(y-\pi^0)(1-p)(1-f)(1-\theta)}{\pi^H - y},\ y \in S \tag{A6}$$

This distribution is atomless. Inserting for $y = \bar{\pi}$ in (A5), we can determine $\bar{\pi}$ as

$$\bar{\pi} = \theta^D \pi^H + (1 - \theta^D)\pi^0 \tag{A7}$$

Insert for $x = \bar{\pi}$ into (A2) to get $k_{inside} = \pi^H - \bar{\pi}$. We can then write (A2) as,

$$(\pi^H - x)G^D(x) = \pi^H - \bar{\pi},\ x \in S \tag{A8}$$

which gives,

$$G^D(x) = \frac{\pi^H - \bar{\pi}}{\pi^H - x},\ x \in S \tag{A9}$$

Notice that this cdf places an atom at $x = \pi^0$, where the magnitude of the atom equals $\frac{\pi^H - \bar{\pi}}{\pi^H - \pi^0}$. We can observe that the induced density function increases in x, since the second derivative of G^D is positive. Furthermore, we can note that when $p < 1$, the inside firm makes positive information rents in the second period (on the high workers). These rents must be offset by negative profits in the first period.

The equilibrium (expected) wage for an agent of type j in the second period equals the expected maximum offer in the bidding before that period. For a low worker, the outside firm determines the expected wage,

$$w_2^E = p\pi^0 + (1 - p)\int_{\pi^0}^{\bar{\pi}} dG^D(z) \tag{A10}$$

The expected wage for a high worker equals,

$$w_2^D = \int_{\pi^0}^{\bar{\pi}} z dG^D(z)F^H(z) \tag{A11}$$

That $w_2^E > \pi^0$ and $w_2^D < \pi^H$ follows directly from $\pi^0 < \bar{\pi} < \pi^H$. Moreover, since $H(.) \equiv G^D(.)F^H(.)$ first order stochastically dominates $G^D(.)$, it follows that $w_2^D > w_2^E$.

We now show that $w_2^D - w_2^E$ monotonically increases in p. In the second period, the outside firm makes zero profits and there is full efficiency. Therefore,

$$\theta\pi^H + (1 - \theta)\pi^0 = \theta w_2^D + (1 - \theta)w_2^E + \theta k_{inside} \tag{A12}$$

On the left hand side is total production in the second period, and on the right hand side are total wages plus profits made by the inside firm. Using the derived expression for k_{inside}, the right hand side of (A12) equals $\theta(w_2^D - w_2^E) + \theta(\pi^H - \bar{\pi}) + w_2^E$, which implies

$$w_2^D - w_2^E = \frac{\theta\pi^H + (1 - \theta)\pi^0 - w_2^E}{\theta} - (\pi^H - \bar{\pi}) \tag{A13}$$

By integrating (A10), w_2^E can be expressed as,

$$w_2^E = p\pi^0 + (1-p)[\bar{\pi} + (\pi^H - \bar{\pi})\ln(G^D(\pi^0)] \tag{A14}$$

Substituting the right hand side of (A14) into (A13),

$$w_2^D - w_2^E = \frac{\theta\pi^H + (1-\theta)\pi^0 - \{p\pi^0 + (1-p)[\bar{\pi} + (\pi^H - \bar{\pi})\ln(G^D(\pi^0)]\}}{\theta} - (\pi^H - \bar{\pi}) \tag{A15}$$

Notice that the only exogenous variables in this expression are p, θ, π^0, and π^H. Normalizing by setting $\pi^0 = 0$ and $\pi^H = 1$, we get,

$$w_2^D - w_2^E = \frac{\theta - (1-p)[\bar{\pi} + (1-\bar{\pi})\ln(G^D(0)]}{\theta} - (1-\bar{\pi}) \tag{A16}$$

Define $z = \dfrac{(1-p)(1-\theta)}{1-p+p\theta} \in [0, 1-\theta]$. Since $\bar{\pi} = 1 - z$ and $(1-\bar{\pi})\ln(G^D(0)) = z\ln(z)$,

$$w_2^D - w_2^E = 1 - z - \frac{(1-p)[(1-z) + z\ln(z)]}{\theta} \tag{A17}$$

Since $\dfrac{dz}{dp} = -\dfrac{(1-\theta)\theta}{(1-p+p\theta)^2} < 0$, the inverse function $p(z)$ exists and equals,

$$p(z) = \frac{1-z-\theta}{(1-\theta)(1-p)} \tag{A18}$$

Therefore, we can substitute in for $1-p = \dfrac{\theta z}{(1-\theta)(1-z)}$ into (A17) to get,

$$w_2^D - w_2^E = 1 - z - \frac{z[1-z+z\ln(z)]}{(1-z)(1-\theta)} \tag{A19}$$

It is then sufficient to show that $w_2^D - w_2^E$ decreases in z for $z \in [0, 1-\theta]$. By differentiating (A19), we find that this condition holds if,

$$(2-z)(z\ln(z) + z\theta + 1) - \theta > 0,\ z \in [0, 1-\theta] \tag{A20}$$

which can easily be verified to indeed be the case. ■

Proof of Proposition 1. In order for a low worker to choose the right task in the first period, the lifetime utility for a low worker for choosing the E task must be at least as high as the lifetime utility for choosing the D task,

$$w_1^E + w_2^E \geq w_1^D + w_2^D \tag{A21}$$

Applying the same argument for a high worker, such a worker chooses the right task if and only if,

$$w_1^D + w_2^D \geq w_1^E + w_2^E \tag{A22}$$

Combining (A21) and (A22), we get that a separating equilibrium must have,

$$w_1^E + w_2^E = w_1^D + w_2^D \tag{A23}$$

(A23) is the double indifference condition referred to in the main text. The only way to ensure an efficient allocation of workers is to set wages such that (A23) holds, and allow workers to choose their task. Hence workers are given full delegation over task choice in a separating equilibrium.

We showed in Remark 1 that $\pi^0 < w_2^E < w_2^D < \pi^H$. It then follows directly from (A23) and zero profits that $w_1^D < \pi^H$ and $w_1^E > \pi^0$. Hence low (high) workers are paid more (less) than their marginal productivity in both periods in a separating equilibrium. To show that high workers have a steeper wage dynamics than a low worker in a separating equilibrium, we need to show that $\Psi^D > \Psi^E$, where

$$\begin{aligned} \Psi^E &= \frac{w_2^E - w_1^E}{w_1^E} \\ \Psi^D &= \frac{w_2^D - w_1^D}{w_1^D}. \end{aligned} \tag{A24}$$

This follows follows straightforwardly from the argument above. ■

Proof of Remark 2. Part i). We show that cream-skimming is more prone to occur the higher p. Abusing notation slightly, denote the wages in a separating equilibrium by $\{w_1^E,\ w_1^D,\ w_2^E,\ w_2^D\}$. We now check under which circumstances $\{w_1^D, w_2^E\}$ are consistent with optimal behavior by firms. First notice that a firm would never raise w_1^D because it would then attract both type of workers to the D job. We therefore need to consider deviations where firms attempt to cream-skim by offering a low wage for the E task and keep the wage offer for the D task constant. Suppose therefore that firm 1 sticks to the wage schedule $\{w_1^E, w_1^D\}$ and firm 2 deviates by offering the wage schedule $\{w'^E_1, w_1^D\}$, where $w'^E_1 < w_2^E$. If firm 2 could commit to such a schedule, it would attract a share of the high workers while all the low workers would choose firm 1. Consequently firm 2 would run a profit, since high workers are paid less than their marginal productivity. However, suppose that a low worker by mistake may also choose to work for firm 2 (the probability of a mistake only needs to be positive). Taking this possibility into account, firm 2 may wish to revise w'^E_1 after the workers have chosen which firm to work for, to make low workers choose the E task rather than the D task, and improve the allocation of workers inside the firm (and profits). Denote this revised offer for w''^E_1. The extra compensation required to make this low worker prefer the E task to the D task would be the loss of career gains from choosing the D task, i.e., $w_2^D - w_2^E$, so that $w''^E_1 = w_1^D + (w_2^D - w_2^E)$. The productivity gain from making a low worker choose the E task instead of the D task would be $\pi^0 - \pi^L$. Hence, a firm would prefer to raise the wage for the E task to w''^E_1 if

$$w_2^D - w_2^E < \pi^0 - \pi^L. \tag{A25}$$

But notice that $w''^E_1 = w_1^E$, and hence cream-skimming by offering w'^E_2 would not be credible if (A25) holds. Consequently, there exists a separating equilibrium when (A25) holds. On the other hand, when (A25) does not hold, a firm can profit by deviating through (credible) cream-skimming, and a separating equilibrium cannot exist. Hence a separating equilibrium is more likely to exist the lower the wage difference $w_2^D - w_2^E$. Since this difference is increasing in p by Remark 1, a separating equilibrium is more likely to exist for lower p.

Part ii) of Remark 2 is proved under Example 1 in Appendix B. ■

8 Appendix B: Rationing Equilibrium

In this appendix, we characterize the rationing equilibrium that occurs when a separating equilibrium does not exist.

Proof of Proposition 2. At this point, we take for given that in a rationing equilibrium, the slots in the E task are rationed and the slots in the D task are freely available. This property of rationing equilibria will be proved at the end.

Let us start out by determining the equilibrium wages $\{w_1^D, w_2^D, w_1^E, w_2^E\}$ for a given level of rationing. Before the second period, the two firms bid for workers conditional on their information, where the inside firm knows the task a worker was engaged in and the outside firm bids conditional on its signal X. Since the auction equilibrium under rationing is very similar to the auction equilibrium without rationing (derived in Remark 1), we merely sketch the former here to save on space.

Let f be the fraction of low workers that are forced into the D task in the first period. Let $\hat{\pi}$ be the average productivity in the D task, i.e., $\hat{\pi} = \dfrac{\theta\pi^H + f(1-\theta)\pi^0}{f(1-\theta)+\theta}$. In the auction before the second period, the outside firm makes zero profits and the inside firm makes the profit Δ_2, where

$$\Delta_2 = (\hat{\pi} - \bar{\pi})(\theta + f(1-\theta)), \tag{B1}$$

where $\bar{\pi} = \phi\hat{\pi} + (1-\phi)\pi^0$, and ϕ is the probability of a given worker been occupied in the D task conditional on $X = D$, i.e.,

$$\phi = \frac{\theta + f(1-\theta)}{f(1-\theta) + \theta + (1-p)(1-f)(1-\theta)} \tag{B2}$$

Notice that $\hat{\pi} - \bar{\pi} = (1-\phi)(\hat{\pi} - \pi^0)$ by the definition of $\bar{\pi}$. Therefore,

$$\Delta_2 = (1-\phi)(\hat{\pi} - \pi^0)(\theta + f(1-\theta)) = (1-\phi)\theta(\pi^H - \pi^0). \tag{B3}$$

The distribution functions that support this solution are,

$$\begin{aligned} F^H(y) &= \frac{(y-\pi^0)(1-p)(1-\theta)(1-f)}{(\theta+(1-\theta)f)(\hat{\pi}-y)}, \ y \in S \\ G^D(x) &= \frac{\hat{\pi}-\bar{\pi}}{\hat{\pi}-x}, \ x \in S, \end{aligned} \tag{B4}$$

As before, the inside firm bids π^0 for a low worker in the E task, and the outside firm bids π^0 for a worker with $X = E$. Furthermore, the profits made on workers in the D task by the inside firm equals $\hat{\pi} - \bar{\pi}$, so that the total profits in the second period of the inside firm equals $(\theta + f(1-\theta))(\hat{\pi} - \bar{\pi})$.

The second period auction equilibrium determines w_2^D and w_2^E as functions of f. The wage difference of the first period, $w_1^E - w_1^D$, can then be determined by the self-sorting constraint, i.e.,

$$w_1^D + w_2^D = w_1^E + w_2^E. \tag{B5}$$

This condition has the same interpretation as in a separating equilibrium. The total wage levels are determined by the overall zero profit constraint $\Delta_1 + \Delta_2 = 0$. For a given degree of rationing f, we have then determined the equilibrium wages $\{w_1^D, w_2^D, w_1^E, w_2^E\}$. We now determine the equilibrium degree of rationing, denoted by f^*.

We begin by putting bounds on f^* from below and from above. First, if a firm can increase its profits by reducing f when bidding for workers in the first period, it would do so. This would be the case if cream-skimming is not a threat. Hence, from below, we have to make sure that f^* is sufficiently high to avoid cream-skimming. Second, we have to make sure that a firm cannot gain by lowering the degree of rationing (and paying workers a compensation to switch) in the interim stage. The first requirement determines that $f^* \notin [0, f_L)$ due to cream-skimming, and the second requirement determines that $f^* \notin (f_H, 1]$ due to lack of renegotiation-proofness. In the following, we shall assume that f_L and f_H are unique, in which case $f^* = f_L = f_H$.

The first period the profit of the inside firm equals Δ_1, where

$$\Delta_1 = \theta(\pi^H - w_1^D) + (1-\theta)[(\pi^L - w_1^D)f + (\pi^0 - w_1^E)(1-f)]. \tag{B6}$$

Suppose that a firm decreases the degree of rationing (and pays workers to switch) at the interim stage. The effect on first period profits from a marginal change in f equals,

$$\frac{d\Delta_1}{df} = -(1-\theta)[\pi^0 - \pi^L - (w_1^E - w_1^D)], \tag{B7}$$

where the firm takes $w_1^E - w_1^D$ as a constant in the interim stage. The first term is the productivity gain and the second term is the added wage bill from changing the degree of rationing in the interim. The effect on the second period profits from a marginal change in the degree of rationing equals the gain a firm makes in the second period auction by knowing more about their workers $K(p, f)$, i.e.,

$$\frac{d\Delta_2}{df} = \frac{d[(1-\phi)\theta(\pi^H - \pi^0)]}{df} = -K(p, f) = -\frac{d\phi}{df}\theta(\pi^H - \pi^0) \geq 0 \tag{B8}$$

A necessary condition for a solution f^* is the following first order condition,

$$\frac{d\Delta}{df} = \frac{d\Delta_1}{df} + \frac{d\Delta_2}{df} = -(1-\theta)[\pi^0 - \pi^L - (w_1^E - w_1^D)] - \frac{d\phi}{df}\theta(\pi^H - \pi^0) = 0 \tag{B9}$$

The intuition is as follows. Suppose that a candidate f^* has $\dfrac{d\Delta}{df} > 0$. Then a firm could credibly cream-skim, as explained under equation (A17), and this candidate is not consistent with equilibrium. Suppose on the other hand that a candidate f^* has $\frac{d\Delta}{df} < 0$. But then a firm could lower the degree of rationing in the interim to increase profits, and also in this case the candidate f^* is not consistent with equilibrium. Whenever there is no solution to (B9) for $f \in (0,1)$ this means that equilibrium will either be separating or pooling.

To ensure that global deviations (i.e., more than incremental changes in f) are not profitable, we impose the following beliefs of firms: a firm beliefs that if it deviates globally from f^* then it will attract a sufficiently high fraction of low workers to never be willing to undertake such a deviation.[29]

Suppose that we have a value of $f \in (0,1)$ that satisfies (B9). Since we allow for f to be renegotiated downwards at the interim stage, we have the additional requirement for f^* to be an equilibrium that $\frac{d^2\Delta}{df^2} < 0$ at f^*.

We can simplify (B9) to make further headway in characterizing equilibria. By the self-sorting constraint, we have that $w_1^E - w_1^D = w_2^D - w_2^E$. We now derive an expression for $w_2^D - w_2^E$ to simplify the first order condition. In the second period, the outside firm makes zero profits and there is full efficiency. Therefore,

$$\theta\pi^H + (1-\theta)\pi^0 = (\theta + (1-\theta)f)w_2^D + (1-f)(1-\theta)w_2^E + (\theta + f(1-\theta))(\hat{\pi} - \bar{\pi}) \quad \text{(B10)}$$

On the left hand side is total production in the second period, and on the right hand side are total wages plus profits made by the inside firm. The right hand side of (B10) equals $(\theta + (1-\theta)f)(w_2^D - w_2^E) + (\theta + f(1-\theta))(\hat{\pi} - \bar{\pi}) + w_2^E$, which implies that

$$w_2^D - w_2^E = \frac{\theta\pi^H + (1-\theta)\pi^0 - w_2^E}{\theta + (1-\theta)f} - (\hat{\pi} - \bar{\pi}) \quad \text{(B11)}$$

By integration, w_2^E can be expressed as,

$$w_2^E = p\pi^0 + (1-p)[\bar{\pi} + (\hat{\pi} - \bar{\pi})\ln(G^D(\pi^0))] \quad \text{(B12)}$$

Substituting the right hand side of (B12) into (B11),

$$w_2^D - w_2^E = \frac{\theta\pi^H + (1-\theta)\pi^0 - \{p\pi^0 + (1-p)[\bar{\pi} + (\hat{\pi} - \bar{\pi})\ln(G^D(\pi^0))]\}}{\theta + (1-\theta)f} - (\hat{\pi} - \bar{\pi}) \quad \text{(B13)}$$

[29] There is an existence of equilibrium problem in the subgame reached after a deviation in f from f^*.

Normalizing by setting $\pi^0 = 0$ and $\pi^H = 1$ (notice that π^L must be negative after the normalization), and inserting for $w_1^E - w_1^D = w_2^D - w_2^E$, we can hence write the first order condition as,

$$\frac{d\Delta}{df} = (1-\theta)[\pi^L + \frac{\theta - (1-p)[\bar{\pi} + (\hat{\pi} - \bar{\pi})\ln(G^D(0))]}{\theta + (1-\theta)f} - (\hat{\pi} - \bar{\pi})] - \frac{d\phi}{df}\theta = 0 \quad \text{(B14)}$$

The parameters of this equation are p, θ, f and π^L. Notice π^L occurs only one place in the equation. Therefore, the profits of moving one worker, $-\frac{d\Delta}{df}/(1-\theta)$, is positive whenever

$$\pi^L < -[\frac{\theta - (1-p)[\bar{\pi} + (\hat{\pi} - \bar{\pi})\ln(G^D(0))]}{\theta + (1-\theta)f} - (\hat{\pi} - \bar{\pi})] + \frac{d\phi}{df}\frac{\theta}{(1-\theta)} \quad \text{(B15)}$$

So switching a worker is more prone to be profitable whenever π^L is low, which is intuitive. Consequently, we can for any p, θ find π_L sufficiently low for a separating equilibrium to exist. We then have the following remark.

Remark 3 *A separating equilibrium is more likely to exist the lower π^L.*

We now move to consider the relation between f^* and p at equilibrium. Assuming that there exists a unique $f^* \in (0,1)$ for a given p, then the condition $\frac{d\Delta}{df} = 0$ implicitly defines a function $f^*(p)$. We now investigate properties of this function. By the implicit differentiation rule,

$$\frac{df^*}{dp} = -\frac{\frac{d^2\Delta}{df\,dp}}{\frac{d^2\Delta}{df^2}} \quad \text{(B16)}$$

For a candidate f^* to be an equilibrium, it needs to be renegotiation-proof, i.e., $\frac{d^2\Delta}{df^2} < 0$. Hence it is necessary to show that $\frac{d^2\Delta}{df^2} < 0$ implies $\frac{d^2\Delta}{df\,dp} > 0$. Unfortunately, the algebraic complexity of the derivatives makes us only able to numerically verify that this condition holds. Numerical analysis confirmed that there exists a unique f^* that satisfies $\frac{d^2\Delta}{df^2} < 0$, and moreover that the function $f^*(p)$ implicitly defined is increasing.[30]

[30] We sampled a million different combinations of (θ, f, p) and was not able to find a counterexample. Furthermore, numerical analysis showed that for intermediate values of p, there are two solutions for f^*, defined by (B9), one which satisfies the renegotiation constraint $\frac{d^2\Delta}{df^2} < 0$, and one that does not.

Let us now derive conditions for existence of a pooling equilibrium. If $\left.\frac{d\Delta}{df}\right|_{f=1} < 0$, then a pooling equilibrium cannot exist, because a firm could make a profit from moving a worker. We now evaluate $\left.\frac{d\Delta}{df}\right|_{f=1}$. First note that $\hat{\pi}$ and $\bar{\pi}$ goes to zero as f goes to 1. As can easily be verified,

$$\lim_{f\to 1}\{[(\hat{\pi}-\bar{\pi})\ln(G^D(0)]\} = 0 \tag{B17}$$

$$\lim_{f\to 1}\frac{d\phi}{df} = (1-p)(1-\theta)$$

$$\lim_{f\to 1}\hat{\pi} = \lim_{f\to 1}\bar{\pi} = \theta$$

Therefore,

$$\begin{aligned}\left.\frac{d\Delta}{df}\right|_{f=1} &= \lim_{f\to 1}\{(1-\theta)[\pi^L + \frac{\theta-(1-p)[\bar{\pi}+(\hat{\pi}-\bar{\pi})\ln(G^D(0))]}{\theta+(1-\theta)f} + \hat{\pi}-\bar{\pi}] - \frac{d\phi}{df}(0) \\ &= (1-\theta)(\pi^L+p\theta)-(1-p)(1-\theta)\theta = -(1-\theta)[\theta\,(1-2p)-\pi^L]\end{aligned} \tag{B18}$$

From this, we see that $\left.\frac{d\Delta}{df}\right|_{f=1} < 0$ if $p < \frac{\theta-\pi^L}{2\theta}$. Since $\pi^L < 0$ we then have the following,

Remark 4 *A pooling equilibrium cannot exist for* $p < \frac{1}{2}$.

Proof. We now prove (ii), that there cannot be rationing equilibrium where the number of slots in task D is restricted. If the number of slots in task D is restricted, there are two possibilities. First, it can be the case that both types wish to work in task D. In that case, the proportion of workers should be the same in both jobs. If this happens, there are no career concerns since no information inferred by task choice. Because of this, the firm can induce a high worker switch from task E to task D, by paying the same wage in task D as in task E. Such a scheme would increase productivity without increasing costs. So in equilibrium, it cannot be the case that both types of workers wish to work in task D. The second possibility is that the low type wishes to work in task E, while the high type workers wish to work in task D. In that case, total wages must be equalized across tasks. But then, the firm can increase profits by allowing a higher fraction of workers in task D, by allowing workers to move from task E to task D (since only high workers would wish to move). This occurs since both the wage in task D is lower than in task E (since the fraction of high workers in task D is higher than in task E) and productivity of high workers is higher in task D. Hence a situation where the slots in task E is rationed cannot be an equilibrium.

To illustrate the solution, we can consider the polar cases $p = 0$ and $p = 1$. ■

Example 1 (Proof of Remark 2ii.) $p = 0$

Proof. For $p = 0$, we have $K(0, f) = (\pi^H - \pi^0)\theta > 0$, which is independent of f. Furthermore, the highest possible wage offered in the support is $\overline{\pi} = \theta\pi^H + (1-\theta)\pi^0$. The inside firm can offer this when the worker is high and make profit $\pi^H - \overline{\pi}$, making the inside firms profit equal to $(\pi^H - \overline{\pi})\theta$. We know that there is full efficiency in the second period and the outside firm makes zero profits so $\theta w_2^D + (1-\theta)w_2^E + (\pi^H - \overline{\pi})\theta = \overline{\pi}$. Rearranging yields $\theta(w_2^D - w_2^E) = (1+\theta)\overline{\pi} - \theta\pi^H - w_2^E$. By substituting in for $\overline{\pi}$ we have $w_2^D - w_2^E = \theta(\pi^H - \pi^0) + (\pi^0 - w_2^E)/\theta < \theta(\pi^H - \pi^0) = K(0, f)$. Thus, the wage difference is less than the knowledge gained and we always have incentive to get workers to sort for $p = 0$ and there cannot be cream-skimming. Therefore, a separating equilibrium always exists for $p = 0$. ■

Example 2 $p = 1$.

Clearly, $\frac{d\phi}{df} = 0$ when $p = 1$, so that $K(1, f) = 0$. Therefore, there must be zero profits in both periods, and equilibrium is the following,

$$\begin{aligned} w_1^E &= \theta(\pi^H - \pi^L) + \pi^0 \\ w_2^E &= \pi^0 \\ w_1^D &= (1-\theta)\pi^L + \theta\pi^H \\ w_2^D &= 2\pi^0 - \pi^L \\ f^* &= \frac{\theta(\pi^H + \pi^L - 2\pi^0)}{(1-\theta)(\pi^0 - \pi^L)} \end{aligned} \tag{B19}$$

As can be seen from this, the degree of rationing is zero whenever $\pi^H + \pi^L - 2\pi^0 < 0$, as shown before. When $f^* \geq 1$, we have a pooling equilibrium, where all workers are assigned to a task. As can easily be shown, the equilibrium will always be pooling for (p, π^H) sufficiently high. As can be shown,

$$\frac{df^*}{dp}_{p=1} = \frac{3 - f - \theta + f\theta}{1-\theta} > 0 \tag{B20}$$

Hence equilibria are stable for $p = 1$. ■

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