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On the Incentive Effect of Job Rotation*

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Abstract

The longer an agent is employed in a job, the more the principal will have learned about his ability through the history of performance. With implicit incentives, influence perceptions and effort incentives decrease over time. Rotating agents to a different job deletes learning effects about ability, creating fresh impetus for effort. However, job rotation also reduces the time horizon, and thus reduces rents from working and also incentives. In this trade-off, we derive conditions for the desirability of job rotation and show how in the presence of career concerns job rotation may emerge endogenously. Finally, our model allows for more general comments on the optimal rotation frequency as well as the preferred organizational design of a firm.

Keywords: Job rotation, Implicit incentives, Learning, Specialization

JEL-Codes: D83, J24, L23

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1 Introduction

Job rotation is a management strategy of periodically transferring employees to different jobs within an organization. Recent empirical research reports a rapid increase in flexible workplace practices, with job rotation as one of the three main characteristics of those practices.¹ For example, workers are rotated through various projects, between tasks in a single department, or even between business units in different regions or countries. Job rotation is not only a tool to fill temporary assignments, but also to rotate people at their regular job on a monthly, weekly, or actually daily basis. Traditional wisdom suggests that there are direct costs and benefits to job rotation that relate to technical aspects of specialization and learning. Obviously, even though rotating an engineer into a sales department can develop new skills, job-specific human capital will be lost and the acquisition of new knowledge is time-consuming. In this paper, we present a new explanation for the use of job rotation and argue that job rotation also has indirect costs and benefits through the effects of information and incentives that relate to a worker's career concerns. We highlight that job rotation is a tool for limiting the amount of performance information available to the market and therefore for modifying the effort incentives of workers.

By investigating the informational and incentive-related role of job rotation, the main contribution of this paper is to emphasize how erasing past performance information by job rotation can create new incentives. More specifically, related to the seminal work of Fama (1980) and Holmström (1999), firms often have to commit themselves to provide implicit incentives to their employees. The attempt to shape the personal skill perceptions serves as an incentive device. If an agent works in a job for a long time, the principal will have learned much about his abilities and thus the incentives to increase the principal's beliefs decrease over time. Job rotation results in an information loss about the agent's abilities and therefore increases his incentives to incur costly effort. However, anticipating rotation, an agent will cut back on his effort in the first place, due to a smaller pay-back period of his effort. These divergent effort interrelations create novel insights into the optimal provision of incentives to workers. One such insight is that, under certain conditions, the agent's average utility is non-monotonic in his rotation frequency.

To formally analyze the incentive role of job rotation, we formulate a principal agent setting with an infinite horizon. A risk-neutral firm owner and an agent with an ex-ante unknown ability engage in an employment relationship where the agent exerts effort to improve the market expectations of his skill and consequently his future compensation. Job rotation deletes past performance signals in drawing inference about the agent's skill and therefore relocates his incentives to incur costly effort. Ex-ante, when the agent's type is little known, effort incentives and influence perceptions about ability are large.

¹Osterman (1994, 2000) documents establishment rates of about 35% for U.S. manufacturing firms with 50 or more employees. Pil and MacDuffie (1996) provide evidence on the adoption of job rotation for assembly plant workers around the world. Based on data in the U.S., Gittleman, Horrigan, and Joyce (1998) report adoption rates of about 40%. In a survey of Danish private sector firms, Eriksson and Ortega (2006) outline that rotation schemes were implemented for nearly 20% of hourly paid workers.

As time goes by, the agent's type is partially revealed and the incentives to exert effort decrease. Also, when the agent comes closer to the rotation date, he becomes lazy because his type is virtually revealed by then, and the information will be erased soon, so why bother to work? Hence, for long maturities, there is overworking in the beginning and underworking towards the rotation date. Furthermore, for a too large rotation frequency, the agent knows that he will not stay on the task for long, so he will not exert much effort in the first place. Consequently, a positive but finite rotation frequency is optimal.

We explore how job rotation influences the agent's effort incentives and average utility in a dynamic perspective. Specifically, if the agent's ability is virtually known *ex ante*, then firms place less reliance on output when forecasting the agent's type and the incentives to incur costly effort are small. A large duration until rotation can raise the agent's incentives to increase beliefs about his type and prevents him from underinvesting in effort. In contrast, the more dispersed the prior, the larger is the impact of the agent's effort on the firms' estimate of his ability. If time until rotation is long, then effort incentives can be inefficiently large, until more information is revealed. The agent can then only achieve the optimal workload by increasing the frequency of rotation. In light of such phenomena, this paper investigates the determinants for an agent's optimal assignment and characterizes the impact of this choice on learning about types and the incentives given to workers.

Altogether, our work contributes to the literature on incentives provided by organizational change and, more generally, to the research on endogenous job design. It allows us to shed light on the complex relationships between organizational assignment, learning effects about ability, the effort incentives given to workers, and their consequences on overall utility within an economic model. Our results offer a novel theoretical approach for the lack of empirical evidence for existing explanations to job rotation that relate to learning about abilities and the motivation of employees, emphasizing that job rotation is less common for incentivizing long-tenured employees with limited future prospects (Campion, Cheraskin, and Stevens (1994), Eriksson and Ortega (2006)).² In a more general context, our results may also explain the recent trends on workplace reorganizations, including the increased dissolution of long-term contracts, rising inter-firm job changes, limited employment durations, the use of flexible staffing, and the adoption of triangular employment relations with many employers and temporary or contingent contracts.³

Literature. Our paper relates to other fields within the existing literature. First, it refers to models on implicit incentives in the presence of career concerns, originating from the seminal work of Fama (1980) and Holmström (1999), who offer explanations for the limitations on explicit payment structures. This work is mostly connected to models that study the influence of career concerns on organizational decisions (Dewatripont, Jewitt, and Tirole (1999b), Bar-Isaac (2007)), as well as the role of information on the strengths

²This employee motivation argument was elaborated in the context of so-called plateaued employees (see Stites-Doe (1996)).

³Several studies provide evidence on workplace restructuring and the implementation of flexible staffing arrangements, primary referring to the US labor market (see, for example, Kalleberg (2000), Gramm and Schnell (2001), Houseman (2001), or Kalleberg, Reynolds, and Marsden (2003)).

of implicit incentives (Dewatripont, Jewitt, and Tirole (1999a), Mukherjee (2008a, 2010), Koch and Morgenstern (2010), Koch and Peyrache (2011)). Related to our approach, Arya and Mittendorf (2011) analyze the impact of organizational decisions as the choice between aggregated and disaggregated performance measures on the incentives given to workers. Although aggregation results in informational drawbacks, it increases the sensitivity of performance measurement to the updating of an agent's ability and with it the incentives to incur costly effort. In line with the basic result that improved information may reduce the strengths of implicit incentives, this paper newly investigates the role of a firm's organizational design as the choice between specialization and job rotation on learning about types and the incentives provided to workers.

Second, several models study the incentive effects of information disclosure and performance feedback when agents face career concerns and effort is history-dependent (Acemoglu, Kremer, and Mian (2008), Gershkov and Perry (2009), Aoyagi (2010), Casas-Arce (2010), Ederer (2010), Goltsman and Mukherjee (2011)). Most connected to our work, Kovrijnykh (2007) presents a model of career uncertainty and analyzes how reputational incentives interact with the possibility of career change. Martinez (2009) investigates how employment history and beliefs about future productivity affect motivation. Similarly, Hansen (2012) studies the effects of interim performance evaluations on agents' incentives to influence beliefs about future effort. While these models primary examine how an agent's effort incentives are influenced by the market expectations of the agent's effort, our work analyzes the relationship between performance information that is determined by an agent's assignment and the strengths of implicit incentives. More specifically, by investigating the effect of current effort on future expectations of an agent's ability, we show how limiting the amount of information available through job rotation impacts learning about an agent's type and therewith relocates the incentives to incur costly effort.

Third, there are parallels to the literature on optimal task assignment (Ricart i Costa (1988), Meyer (1991, 1994), Bernhardt (1995), Ortega (2003), Bar-Isaac and Hörner (2011)). These models concentrate on technological questions related to the optimal task assignment and its implications for learning about agents' abilities, wage levels, promotion decisions, and the associated incentives, including considerations regarding the external labor market. Our approach is also tied to the general analysis on optimal contract length that is based on implicit contracting. Here, our work most closely relates to Jovanovic (1979) who studies a model of optimal job matching where an agent learns his productivity through the observation of output. Turnover is created when the agent's job-specific productivity turns out to be low, while the agent remains in the current job if he forms a good match with the firm. Similarly, Cantor (1988) analyzes how a worker's effort incentives and recontracting costs relate to the length of a labor contract when agents face career concerns. The impetus behind this work is to investigate the information- and incentive-based role of job rotation. Therefore, an agent's task assignment and the optimal retention duration in a job are considered as strategic instruments to shift the effort incentives provided to agents, influenced by learning effects about their abilities and therefore by future compensation.

Forth, several models directly address the reasons why job rotation is useful. With regard

to incentive-based explanations, Ickes and Samuelson (1987) argue that if higher efforts yield more demanding future remuneration schemes, agents are incentivized to cut back on their effort. Job rotation resolves this ratchet effect by disentangling the influence of current performance on future incentives. However, it results in a loss of specific human capital. Carmichael and MacLeod (1993) show that if workers are trained in more than one job, they will be motivated to reveal labor-saving technical change compared to single-skilled workers, as the former can be transferred to other jobs inside the firm and therefore are not threatened with dismissal. Cosgel and Miceli (1999) assume that job rotation reduces the boredom of monotonous jobs, but, on the other hand, suffers the loss of job-specific human capital. Eguchi (2005) outlines that job rotation can prevent agents from performing private activities within their regular work, as these become more profitable as tenure increases. Recent literature analyzes informational benefits of job rotation, either related to learning about the productivity of tasks (Arya and Mittendorf (2004)), or about the productivity of employees ((Meyer, 1994), Ortega (2001), Arya and Mittendorf (2006a,b), Prescott and Townsend (2006), Müller (2011)). Specifically, Arya and Mittendorf (2004) argue that job rotation helps to extract information about the productivity of tasks from employees, as this information can no longer be used against them in the case of rotation. In contrast, Ortega (2001) analyzes job rotation as an instrument to learn a few traits about many dimensions of a worker's ability instead of to learn a great deal about only a few dimensions. Arya and Mittendorf (2006a) focus on sorting benefits of job rotation, based on the result that only versatile employees optimally self-select themselves into rotation programs. Finally, Müller (2011) argues that job rotation leads to multiple performance evaluations of workers. This resolves confirmatory bias problems faced by supervisors, although job rotation sacrifices job-specific human capital. Our work relates to the incentive-based role of information with regard to job rotation and presents a complementary approach that is not linked to typical technological reasons for and against job rotation. Moreover, in contrast to the previous literature, job rotation represents an instrument for reducing the information about agents' abilities and thereby for systematically channeling their efforts towards increases in the benefits of a company's workforce.

From the standpoint of the literature on employee turnover, our paper most closely relates to Höfler and Sliwka (2003), who analyze the impact of managerial replacement on effort incentives provided to workers. In their paper, the dismissal of a manager results in a positive effort effect, based on an increased uncertainty about the subordinates' relative abilities. On the other hand, it reduces the quality of task allocation due to the loss of information. This work contributes to the growing literature on information and incentives provided by organizational change and highlights how in the presence of implicit contracts job rotation may emerge endogenously. Therefore, in addition to positive effort effects, our paper also focuses on negative effort incentives caused by the loss of past performance information. We consider a firm's optimal organizational assignment, clarify the advantages and drawbacks of job rotation programs, and present a new instrument for influencing learning effects about ability. Altogether, our paper focuses on the efficient provision of incentives to workers and creates novel insights into the longstanding debate on the optimal internal design of organizations.

The remainder of this paper is organized as follows. Section 2 develops the main model, and section 3 investigates the trade-offs of an agent’s optimal rotation frequency. Section 4 provides evidence regarding job rotation and discusses the implications of the model. Section 5 contains our conclusions. All proofs are available in the Appendix.

2 The Model

We develop a dynamic principal agent setting with an infinite horizon. Consider a competitive labor market where, at some point in time, $t = 0$, one out of many identical firms (the principal) employs an agent for the purpose of production. At heart of this model we study the agent’s optimal organizational assignment that is given by some T : after T periods the agent will be rotated to a different job inside the firm. To abstract from integer problems, we assume that the agent works continuously on a task. Aggregate output $Y(t)$ after time t , with $0 \leq t \leq T$, is an additively linear function of the agent’s unobservable ability, a , his endogenous effort choice e , and an error term, ε , and is given by

$$Y(t) = at + \int_0^t e dt + \varepsilon. \quad (1)$$

To avoid signaling issues associated with mixed strategies, we assume that all market participants share common prior beliefs about the agent’s ability a that is normally distributed with zero mean and variance α^2 . This implies that the agent himself does not know his type as, otherwise, a high type could go for different contracts than low types. By working on a task, principal and agent learn about the agent’s ability over time through the observation of output. The agent’s ability a and the error term ε are independently distributed, where ε follows a normal distribution with zero mean and a variance that depends on the time span t . We assume that ε has variance $\sigma^2 t$. This assumption has the following micro-foundation. Suppose that aggregate working time can be divided into infinitesimal time intervals. Then, with independent increments, for a time span of length dt , output is given by

$$dY(t) = a dt + e dt + \sigma dW(t), \quad (2)$$

where $W(t)$ is a Wiener process generating noise. According to the basic properties of the standard Wiener process, $W(t)$ has zero mean and variance t . Then, output $Y(t)$ after time t is normally distributed with mean $at + \int_0^t e dt$ and with variance $\sigma^2 t$. It follows that the larger the interval of observation, the smaller is the variance of the output measure relative to time t , and the more precise is then the updating of an agent’s ability. Consequently, the longer the agent works on a task, the more obvious his true abilities will become; the less noise there will be.

Our main focus is to analyze the incentive effect of rotating the agent to a different job. Therefore, we investigate the informational role of job rotation that relates to the observability of the history of an agent’s productivity. We assume that job rotation deletes previous performance information in drawing inference about the agent’s skill and take

complete deletion of information as the extreme case. This independence assumption guarantees that no information about past performance signals is transmitted to the new working department as well as to the outside labor market and involves drawing a new value of the agent's ability. Moreover, as information that is once inside the market cannot be unlearned at a later period, this assumption implies that the market cannot observe past performance signals, but rather that performance signals are private information of principal and agent. Consequently, we refer to an evaluation system where the final working department completes an agent's written character at the end of employment.⁴

To capture incentives of career reputation, we assume contract incompleteness in that output is observable, but not verifiable. That is, the principal cannot write a pay-for-performance contract based on output and is restricted to fixed wage payments, determined by a competitive labor market and conditioned on observed output. The desire to shape the principal's expectation of the agent's skill may therefore provide an impetus for effort. However, effort is costly with a quadratic cost structure of

$$c(e) = c \frac{e^2}{2}. \quad (3)$$

Then, in each period of length dt , an effort $e \geq 0$ increases output by $e dt$, but has a cost of $c(e) dt = c e^2/2 dt$.

Competition for the worker is modeled as follows. We assume that the agent has all bargaining power at contract negotiation, reflecting a competitive labor market that consists of many homogeneous firms. In this case, the agent proposes the initial contract and is free to choose any period length T until rotation. Moreover, we assume that at each renegotiation stage $t \in [0, T]$, the firm faces sufficiently large delay costs if a consensus decision is not achieved. These delay costs reflect the firm's impatience in ex post renegotiation implying that the agent keeps all the bargaining power to propose subsequent contracts.⁵ Thus, at each date $t \in [0, T]$, the agent makes a take-it-or-leave-it offer to the firm. The firm can either accept the offer or dismiss the agent. This condition requires that at each renegotiation stage, the minimum expected utility necessary to induce a firm to hire the agent must yield the firm at least zero expected utility. Stated differently, as the agent has bargaining power over pay, he ultimately reaps all the benefits from employment and becomes residual claimant of the aggregate surplus. Hence, at each date, the agent's wage moves up and down. The agent dislikes spending effort and benefits from compensation.

⁴Similarly, Prescott and Townsend (2006) analyze a principal-agent model with multiple-stage production and assume that job rotation hinders agents in becoming informed about a project's interim performance measures. Also Höfler and Sliwka (2003) assume that after dismissing a manager, the successor receives no information about an agent's past performance signals, neither from the old manager, nor from the principal. Likewise, in a dynamic model of reputation, Bar-Isaac (2007) assumes that an agent's productive history is only observable at the location where it is produced, while the agent's reputation is lost if he moves to a different location.

⁵Aghion, Dewatripont, and Rey (1994) outline that the allocation of full bargaining power in ex post renegotiation to one contractual party represents a well-founded assumption, as it can be achieved by established contractual instruments, such as penalties, or default options.

Consequently, at each date t , the agent's utility is represented by

$$U_t = w_t - c \frac{e_t^2}{2} = E[a_t + e_t + \varepsilon_t] - c e_t^2/2 = E[a_t + e_t] - c \frac{e_t^2}{2}, \quad (4)$$

as $E[\varepsilon_t] = 0$ for all t .

As the agent himself learns his ability over time, his ex ante commitment to T might turn out to be suboptimal. In detail, to limit the visibility of his type, an agent who turns out to be of low ability might choose to rotate more frequently than in the initial steady state. Contrary, a high ability type might prefer to stay in the job for a longer time period such that his abilities will remain apparent. We refer to T as the choice of technology and assume that the agent's ex ante rotation decision is irreversible ex post. That is, once chosen, it is prohibitively costly for the agent to change his rotation date at a future period $t < T$.⁶ Given that all job separations are at the agent's initiative, this also applies for the case where the agent induces the firm to dismiss him purely for the purpose of recontracting his rotation frequency. This assumption strengthens the trade-off between information and incentives that relates to the agent's employment without affecting bargaining and the information structure with respect to the outside labor market.

The timing of the model is as follows.

$t = 0$ One of many identical firms employs an agent with an unknown ability a .

The agent commits to a binding duration until rotation T .

$t < T$ The agent works continuously on a task and exerts effort e .

At each date, firm and agent learn output $Y(t)$ to update the agent's expected ability.

The agent continuously renegotiates his wage w_t by making a take-it-or-leave-it-offer to the firm.

$t = T$ Payoffs are realized.

The firm rotates the agent to a different job, and past performance signals are deleted.

3 Timing of Rotation

In order to investigate how incentives and output interact with the agent's assignment, we will analyze how the timing of rotation relates to learning about the agent's ability.

⁶Similarly, Mukherjee (2008a, 2010) analyzes a firm's optimal disclosure policy and assumes that a firm's ex ante choice of job design is irreversible ex post. Also in the model of Mukherjee and Vasconcelos (2011) a firm's task assignment decision is binding and cannot be revised at a future date. Likewise, Poutvaara, Takalo, and Wagener (2012) study a model of optimal contract duration where the possibility of premature contract renegotiation is excluded.

From a dynamic perspective, as job rotation deletes past performance information in drawing inference about the agent's skill, it may have ambiguous effects on expected future wages, the incentives to incur costly effort, and with it also on the agent's utility. Specifically, the agent's incentives to exert costly effort stem from the desire to increase his productivity in order to improve the market expectation of his ability. That is, the agent maximizes his expected utility, given the market expectations of his effort. Being aware of the agent's utility function, the market anticipates the agent's effort level. Consequently, in equilibrium, the agent's optimal effort corresponds with the market expectation of his effort. As ability and effort additively increase the agent's productivity, learning is not affected by the market expectation of the agent's effort. That is, taking the market expectation of the agent's effort as given, we can only look at whether the agent has an incentive to unobservedly increase efforts. In detail, if the agent increases his efforts while the market believes he does not, his future wages increase because the market partly assigns the resulting productivity increase to an increase in his ability. However, even though the agent's efforts can't be observed, one essential equilibrium condition is that there are no asymmetries between the agent who knows his effort choice and the market in anticipating the agent's unobservable actions. Only this condition implies that in equilibrium, the market is not fooled such that learning effects and the expectations of the agent's ability are consistent for both the market and the agent. This, in turn, implies that if the agent increases his efforts (beyond the market expectations) to establish a favorable reputation of being a high type, the market will anticipate the agent's actions and attribute the increase in productivity to an increase in effort. However, the agent's effort is also chosen accurately to the effect that any effort reduction would be recognized as a signal of lower ability. Furthermore, as the agent is paid his expected productivity, effort is incentive-compatible. That is, the agent receives all the benefits from employment and profits from the resulting output increase in the end, but has to bear the effort costs.

To begin with, assume that the agent is at date $t < T$, and he has already produced $Y(t)$. Then, according to (1), the distribution of the output $Y(t)$ results from the distributions $a \sim \mathcal{N}(0, \alpha^2)$ and $\varepsilon \sim \mathcal{N}(0, \sigma^2 t)$. Consequently, updating follows from

$$Y(t) - \int_0^t \hat{e} dt = at + \varepsilon \sim \mathcal{N}(0, \alpha^2 t^2 + \sigma^2 t), \quad (5)$$

where \hat{e} denotes the market conjecture of the agent's effort. The variance of the output is the sum of the variances of the prior and of the error term. It follows that the variance of the output always exceeds the variance of the agent's ability as it also incorporates measurement error. However, the larger the interval of observation, the smaller is the variance of the output measure relative to the time span t and the updating of the agent's ability is then more precise. As the agent's equilibrium effort is anticipated, the market uses $Y(t) - \int_0^t \hat{e} dt$ to forecast the agent's ability. According to the Bayes' theorem for normally distributed random variables, the agent's perceived type is then normally distributed with

mean (expected type)

$$\begin{aligned}\hat{a} &= E \left[a \mid Y(t) - \int_0^t \hat{e} dt \right] = \frac{1}{t} \left(\underbrace{\frac{\sigma^2 t}{\alpha^2 t^2 + \sigma^2 t}}_{:=q} 0 + \underbrace{\frac{\alpha^2 t^2}{\alpha^2 t^2 + \sigma^2 t}}_{:=1-q} \left(Y(t) - \int_0^t \hat{e} dt \right) \right) \\ &= \frac{\alpha^2}{\alpha^2 t + \sigma^2} \left(Y(t) - \int_0^t \hat{e} dt \right).\end{aligned}\quad (6)$$

The posterior variance of the agent's ability results from the precisions of both the prior and of the conditional variances and equals

$$\hat{\alpha}^2 = \frac{1}{t^2} \left(\frac{1}{1/(\alpha^2 t^2) + 1/(\sigma^2 t)} \right) = \frac{\alpha^2 \sigma^2}{\alpha^2 t + \sigma^2}.\quad (7)$$

Then, the *a posteriori* distribution of the agent's ability, after observation of $Y(t)$, is given by

$$\hat{a} = E \left[a \mid Y(t) - \int_0^t \hat{e} dt \right] \sim \mathcal{N} \left(\frac{\alpha^2}{\alpha^2 t + \sigma^2} \left(Y(t) - \int_0^t \hat{e} dt \right), \frac{\alpha^2 \sigma^2}{\alpha^2 t + \sigma^2} \right).\quad (8)$$

The agent's expected ability in period t consists of a weighted average of the prior \hat{a}_0 (which equals zero), and of the signal $Y(t) - \int_0^t \hat{e} dt$. The sum of both weights is 1 in each case; thus, the weight on the prior, denoted q , increases if the new information is very noisy (large σ). Contrary, if the prior is very noisy (large α), more weight is put on the output measure $1 - q$. Furthermore, learning reduces the variance of the agent's expected ability such that its estimation becomes more precise. Equivalently, the increase in $Y(t) - \int_0^t \hat{e} dt$ is approximately proportional to $a t$ such that if tenure tends to infinity, $t \rightarrow \infty$, the agent's expected ability converges to the real ability, $\hat{a} \rightarrow a$, and its variance converges to zero, $\hat{\alpha}^2 \rightarrow 0$. That is, updating reduces the uncertainty about the agent's ability α , it consequently reduces further learning effects, and with it also the strengths of implicit incentives. Based on this basic result that increased information may reduce future incentives, the main focus of our work is to analyze how job rotation can disentangle future output from past learning effects and therefore relocate the agent's incentives to incur costly effort.

Taking the firms' expectations of the agent's effort as given, assume that at date t , the agent increases his effort by an infinitesimal de for an infinitesimal time span dt . That is, for the remaining $T - t$ periods until rotation, aggregate output is increased by $de dt$. Hence, the agent expects that for all dates $t' \in [t, T]$, the firms' expected value of the agent's type is

$$\frac{\alpha^2}{\alpha^2 t' + \sigma^2} (Y(t') + de dt).\quad (9)$$

That is, it is increased by

$$\frac{\alpha^2}{\alpha^2 t' + \sigma^2} de dt.\quad (10)$$

As, at each date t , the agent is paid his expected marginal product, his aggregate wage from t to T increases by

$$de dt \int_t^T \frac{\alpha^2}{\alpha^2 t' + \sigma^2} dt' = de dt \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right]. \quad (11)$$

The agent will increase his effort as long as the perceived benefits exceed the costs associated with this increase. The cost function is $c e^2/2$, hence the additional cost for this effort increase is $c de^2/2 dt$. The first order condition thus yields

$$c de^2/2 dt = de dt \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right]. \quad (12)$$

This gives the following lemma.

Lemma 1 *The agent's equilibrium effort is*

$$e^* = \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right] / c. \quad (13)$$

Lemma 1 outlines a few basic characteristics of the agent's optimal effort e^* . Intuitively, as job rotation deletes past performance information in drawing inference about the agent's skill, effort is only worthwhile for $t < T$. Consequently, when the duration until rotation is extended, the wage derived from effort increases. Hence, the optimal effort increases with the payback period $T - t$. The effect of career concerns incentives implies that if skill is known, $\alpha = 0$, the optimal effort is zero, $e^* = 0$. That is, the larger the prior type uncertainty (large α) and the more precise the performance measurement (small σ), the larger are the incentives to invest in increasing visibility and the more effort the agent spends in equilibrium.

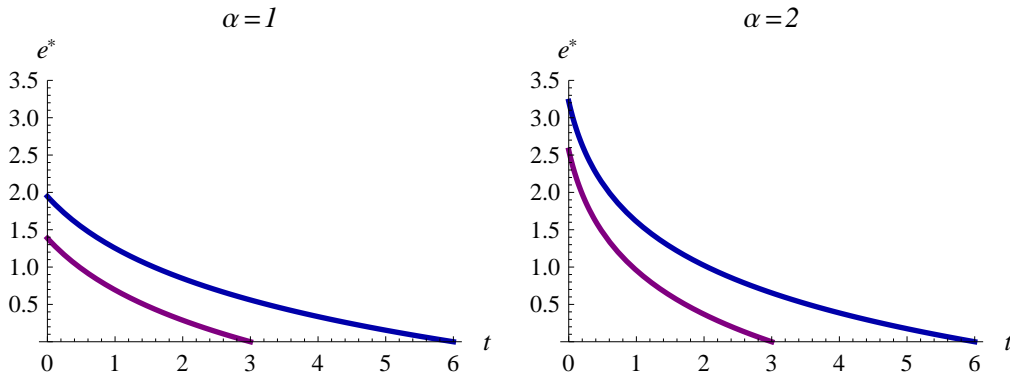


Figure 1: Optimal effort e^* as a function of time t

The parameters are $\sigma = 1$, $c = 1$, $\alpha = 1$ (left figure), and $\alpha = 2$ (right figure). We have $T = 6$ for the blue curve, and $T = 3$ for the purple curve.

Figure 1 shows the equilibrium effort e^* as a function of time t when varying the duration until rotation T and given different values of the prior type uncertainty α . Three things are visible. *First*, by comparing the left and right figures, the higher the uncertainty about the agent's type α , the more the agent has to prove, and the more effort he spends. *Second*, the longer the time until rotation $T - t$, the higher the uncertainty about the type, and the longer the agent can benefit from a wage increase from effort. Thus, for small t , effort is high. As time reaches $t = T$, the agent does not spend any effort at all. *Third*, the functions are convex in t . If the second effect were the only time effect prevalent, then the effort should be linear in $T - t$. It is not. This means that the additional information that is aggregated over time plays an important role. In detail, firms not only place less weight on output when prior type uncertainty decreases, but they also are less likely to change their old estimate. Thus, at the beginning (for small t), the agent's type is little known, hence incentives to exert effort and influence perceptions about the type are large. As time goes by (for larger t), the agent's type is partially revealed, hence incentives to exert effort decrease.

Our results indicate that the strengths of career concerns decline as performance information accumulates such that learning effects about ability and the worker's future wage become less sensitive to output over time. *First*, for long maturities, an agent might overinvest in effort at the beginning, but underinvest in effort when coming closer to the rotation date, as all performance information will be erased soon. *Second*, for a too large rotation frequency, an agent might exert less effort in the first place as effort pays off for not very long. This yields the final question: how large is the optimal duration until rotation T^* ? As the firm's profit is zero, we need to aggregate the agent's utility over time and calculate the agent's average. This is because the number of assignments increases with the agent's rotation frequency. At each date t , the agent is paid his expected productivity, hence his utility is

$$w_t - c \frac{e_t^2}{2} = E[a_t + e_t] - c \frac{e_t^2}{2}.$$

The average is then

$$\begin{aligned} \bar{U} &= \frac{1}{T} \int_0^T \left[E[a_t + e_t] - c \frac{e_t^2}{2} \right] dt \\ &= \frac{1}{T} \int_0^T \left[E \left[a_t + \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right] / c \right] - \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right]^2 / (2c) \right] dt \\ &= \frac{\sigma^2}{2c\alpha^2 T} \log \left[1 + \frac{\alpha^2 T}{\sigma^2} \right]^2. \end{aligned} \tag{14}$$

This average depends on the cost factor c , of course, and on the fraction $\alpha^2 T / \sigma^2$. Intuitively, if performance measurement is very noisy (large σ), learning effects are small and the effect of effort is low. A large duration until rotation T increases the payback period of the agent's effort and can incentivize him to spend more effort. Contrary, if the prior is highly dispersed (large α), learning effects and effort incentives are large. Cutting back the duration until rotation can prevent the agent from overworking such that smaller

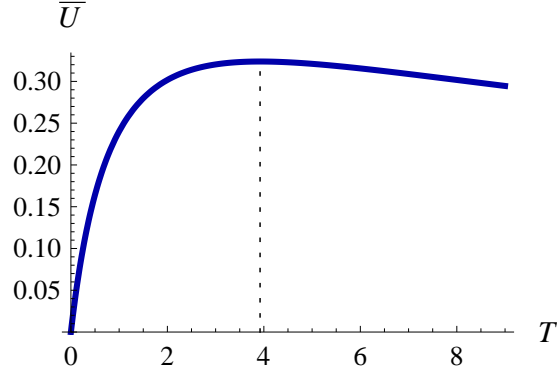


Figure 2: Agent's average utility \bar{U} as a function of the duration until rotation T

The parameters are $\sigma = 1$, $c = 1$, and $\alpha = 1$, as before. The dashed line gives the optimal duration until rotation T^* .

values of T are optimal. In other words, job rotation smooths effort incentives over time and therefore may increase the agent's utility due to convex effort costs. Figure 2 shows the agent's average utility over time, as dependent on the duration until rotation T . We are interested in the optimal duration T^* (in the picture, a little smaller than 4). The first order condition, $\partial\bar{U}/\partial T = 0$, yields

$$0 = \left(1 + \frac{\alpha^2 T^*}{\sigma^2}\right) \log \left[1 + \frac{\alpha^2 T^*}{\sigma^2}\right] - 2 \frac{\alpha^2 T^*}{\sigma^2},$$

$$T^* = \frac{\sigma^2}{\alpha^2} T_1, \tag{15}$$

where T_1 is the solution to

$$0 = (1 + T_1) \log [1 + T_1] - 2 T_1,$$

$$T_1 \approx 3.9215. \tag{16}$$

This proves the following proposition.

Proposition 1 *The optimal duration until rotation is $T^* = 3.9215 \cdot \sigma^2/\alpha^2$.*

The optimal rotation frequency is thus $1/T^* = 1/T_1 \cdot \alpha^2/\sigma^2 \approx 0.2550 \cdot \alpha^2/\sigma^2$. The better the agent's type is already known ex ante, in comparison to the variance of the noise ε , the smaller is α , and the less he should be rotated within the firm. Why? If the agent's type is virtually known (small α), then his incentives to work are small and suboptimal. Therefore, he needs to be incentivized to spend more effort, and this can be achieved by giving him a long horizon, so the incentives to increase beliefs about his type are higher. In fact, not only does he need to be incentivized, he also wants to be incentivized more because ultimately, he reaps all the benefits himself. If his type is virtually unknown

(large α), he has an incentive to work like crazy especially in the beginning, until more information is revealed. Potentially, he might even overwork. If time until rotation is long, incentives to work can be inefficiently large. The agent can then only achieve the optimal workload by cutting down the duration until rotation, hence by increasing the rotation frequency.

Considering the perspective of the (unmodeled) periods beyond rotation, $t \geq T$, suggests that the optimal duration until rotation T^* may become subject to mixed strategies, as the agent will have superior information about his abilities compared to other market participants if human capital is not job-specific. Otherwise, the optimal duration until the following rotation will always remain the same as in the first equilibrium and therefore will maximize the agent's infinite horizon profits.

Our general results indicate that the optimal rotation frequency $1/T^*$ is small, when noise is primary induced by the uncertainty about external shocks σ rather than by the uncertainty about the agent's type α . That is, the optimal duration until rotation T^* increases when the noise of performance measurement increases, or the variance of ability decreases. For any such change, learning effects about ability decrease and the market is less likely to change the initial perception about the agent's type. Consequently, incentives to invest in visibility decrease such that the agent needs to be incentivized by a longer pay-back period of his effort; that is, a larger duration until rotation. In the extreme case, when prior type uncertainty tends to zero, $\alpha \rightarrow 0$, the optimal time until rotation tends to infinity, $T^* \rightarrow \infty$, and thus the optimal rotation frequency tends to zero, $1/T^* \rightarrow 0$. Consequently, a major result is that job rotation can only be beneficial in case when career uncertainty exists.

4 Implications and Discussion

With regard to empirical evidence, a study by Eriksson and Ortega (2006) reappraises three major explanations for the adoption of job rotation: employee learning, employer learning, and employee motivation. While our model rules out the possibility of typical technological arguments to job rotation, such as the acquisition of new knowledge through exposure to different tasks (employee learning hypothesis), it is consistent with stylized facts that relate to the employer learning and the employee motivation hypothesis. The employee motivation argument assumes that job rotation should incentivize long-tenured employees with limited advancement opportunities. Contrary, the employer learning argument focuses on job rotation as an instrument to learn different traits of a worker's ability. Abstracting from such multi-branched learning effects, our results propose a complementary explanation, one that connects learning effects about ability with incentive-related evidence for job rotation. In the argumentation of our model, a firm learns more about an agent's ability if prior type uncertainty is large and if performance measurement is relatively precise. In this case, agents should rotate more frequently. Consequently, of interest is, when the prior type uncertainty is likely to be large in comparison to the noise of performance measurement. *First*, at lower hierarchical levels, job design takes the form of

standardized tasks and routine work is more common. That is, exogenous shocks are more likely to persist at higher hierarchical tiers, as projects become more complex and also may include or at least depend on the contributions of other agents. Here, performance measurement is less precise and thus learning effects about ability are small. *Second*, type uncertainty should decrease with an agent’s work experience in the labor market. Consequently, the frequency of rotation should be smaller for senior workers and higher for new hires and employees at lower hierarchical levels of a firm. Consistent with this result, Campion, Cheraskin, and Stevens (1994) identify a negative relationship between self-selection into rotation programs and organizational tenure. With regard to different hierarchical occupations, employees with more routine work, like clerical workers, secretaries, and administrative assistants generally prefer higher rotation rates than executives. Similarly, Eriksson and Ortega (2006) emphasize that the implementation of job rotation negatively relates to employees’ tenure. Moreover, promotion prospects and rotation rates are shown to be higher at new or fast-growing firms. Likewise, our model accounts for the finding that firms with flatter hierarchical structures and therefore limited prospects of promotion generally face lower rates of rotation. Therewith, our results offer a novel theoretical explanation for the lack of empirical evidence for existing motivational approaches to job rotation identifying that job rotation is less common for motivating plateaued employees without future prospects, but more plays a role for agents with shorter employee tenure, such as young professionals, who are primarily incentivized by career concerns objectives.

5 Conclusion

In this paper, we offer a new information- and incentive-based explanation for the use of job rotation. By considering the question of an agent’s optimal task assignment, we highlight how in the presence of implicit incentives job rotation may emerge endogenously. More specifically, our model shows that learning about an agent’s ability and the incentives to incur costly effort decrease over time. Rotating agents to a different job results in an information loss about past performance signals, creating new impetus to effort. However, job rotation also reduces the time horizon and thus reduces rents from working and incentives. In this trade-off, our model analyzes the impact of environmental variables on the desirability and the optimal extent of job rotation. As a result, the optimal duration until rotation increases as incentives to increase beliefs about the agent’s type decline. Thus, the more dispersed the prior relative to the noise of performance measurement, the more often agents should be rotated inside the firm.

By analyzing a firm’s optimal organizational strategy, the main contribution of our work is to characterize how implicit contracts impact optimal job design and how employees may benefit from job rotation programs. Therefore, we offer a new explanation for the lack of empirical evidence connecting employer learning arguments with existing motivational approaches to job rotation. In line with the findings that job rotation is more common among young employees and therefore is not appropriate for reducing the boredom of long-tenured workers (Campion, Cheraskin, and Stevens (1994), Eriksson and Ortega (2006)), we present a novel motivational explanation for the use of job rotation, confirming that job

rotation can be advantageous in the presence of implicit incentives and hence is more effective in early careers of employees. More generally, abstracting from the traditional view that technical factors, such as the implementation of a new technology, can promote the implementation of job rotation (see, for example, Gittleman, Horrigan, and Joyce (1998)), we propose that information and incentives also play a pivotal role in the desirability of job rotation and the question of the optimal organizational strategy of firms. Our results are consistent with recent empirical evidence emphasizing the role of information with regard to job rotation and the incentives given to workers (Hertzberg, Liberti, and Paravisini (2010), Hentschel, Muehlheusser, and Sliwka (2012)).⁷

Our model implies that job rotation is not meant to be a panacea for the provision of incentives to workers; rather it is a means that should be used in moderation to establish a proper balance between effort incentives in the early and later periods of an agent's employment. This is because job rotation is related to both positive and negative incentives that are based on learning effects about ability. Based on these results, several theoretical extensions of this model can be considered. One aspect would be to extend the model framework by analyzing the interaction of job rotation with other forms of incentive-enhancing policies, such as monitoring activities. Specifically, monitoring could increase the precision of output measurement and therefore complement the incentive effect of rotation programs. Another consideration would be to investigate the implementation of job rotation in team settings. The entering of a new team agent would introduce uncertainty concerning the relative abilities of all team members and therefore can create effort incentives even for non-rotating employees, especially in the presence of aggregated or relative performance evaluations.

Taking a broader view of the results, our work contributes to the debate on the optimal internal design of organizations. Although the implementation of job rotation can also be affected by other factors, such as organizational requirements, our model offers a new understanding of how job rotation impacts learning effects about abilities and influences the behavior of agents through their career concerns incentives.

Appendix

Proof of Lemma 1. At date t , the agent can spend effort costs $ce^2/2$ such that for the remaining time period of $t' \in [t, T]$ output is increased by e . More specifically, at date t , an effort cost of $cde^2/2 dt$ increases output from t to T by $de dt$. Thus, as the agent's wage proportionally increases with his expected ability, it is increased for all dates $t' \in [t, T]$ by

$$(1 - q) de dt = \frac{\alpha^2}{\alpha^2 t' + \sigma^2} de dt, \quad (17)$$

⁷Hertzberg, Liberti, and Paravisini (2010) find evidence that job transfers and the anticipation of rotation can remove loan officers' incentives to withhold bad news, as self-reporting has a smaller negative effect on their career than if bad news is uncovered by the successor. In relation to the literature on employee turnover, Hentschel, Muehlheusser, and Sliwka (2012) identify that managerial replacement can increase the subordinates' incentives to demonstrate their skills.

where $1 - q$ denotes the weight on the output measure when updating the agent's ability. Consequently, according to (10), (11), and (12), the agent balances the resulting benefits with his costs of effort. Thus, the agent solves

$$\max_e de dt \int_t^T \frac{\alpha^2}{\alpha^2 t' + \sigma^2} dt' - c \frac{de^2}{2} dt = de dt \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right] - c \frac{de^2}{2} dt. \quad (18)$$

The first-order condition yields the equilibrium effort of

$$e^* = \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right] / c, \quad (19)$$

which corresponds to the result of (13). Note that as e^* is free of the market conjectures, the existence of a unique equilibrium is ensured. \blacksquare

Proof of Proposition 1. According to (4), at each date $t \in [0, T]$, the agent is paid his expected productivity, $w_t = E[a_t + e_t + \varepsilon_t] = E[a_t + e_t]$. Then, applying the equilibrium effort e^* of Lemma 1, and given the distributions $a \sim \mathcal{N}(0, \alpha^2)$ and $\varepsilon \sim \mathcal{N}(0, \sigma^2 t)$, the agent's average utility is given by

$$\begin{aligned} \bar{U} &= \frac{1}{T} \int_0^T \left[E \left[a_t + \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right] / c \right] - \log \left[\frac{\alpha^2 T + \sigma^2}{\alpha^2 t + \sigma^2} \right]^2 / (2c) \right] dt \\ &= \frac{\sigma^2}{2c\alpha^2 T} \log \left[1 + \frac{\alpha^2 T}{\sigma^2} \right]^2, \end{aligned} \quad (20)$$

which corresponds to the result of (14). The agent solves for the optimal duration until rotation T^* ,

$$\max_T \bar{U} = \frac{\sigma^2}{2c\alpha^2 T} \log \left[1 + \frac{\alpha^2 T}{\sigma^2} \right]^2. \quad (21)$$

The first order condition, $\partial \bar{U} / \partial T = 0$, yields

$$0 = \left(1 + \frac{\alpha^2 T^*}{\sigma^2} \right) \log \left[1 + \frac{\alpha^2 T^*}{\sigma^2} \right] - 2 \frac{\alpha^2 T^*}{\sigma^2}, \quad (22)$$

which corresponds to the result of (15). With $T^* = \sigma^2 / \alpha^2 T_1$, we can rewrite (22) to

$$\begin{aligned} 0 &= (1 + T_1) \log [1 + T_1] - 2 T_1, \\ T_1 &\approx 3.9215. \end{aligned} \quad (23)$$

That is, the optimal duration until rotation is $T^* = \sigma^2 / \alpha^2 \cdot T_1 \approx 3.9215 \cdot \sigma^2 / \alpha^2$. The optimal frequency of rotation then equals $1/T^* = 1/T_1 \cdot \alpha^2 / \sigma^2 \approx 0.2550 \cdot \alpha^2 / \sigma^2$. \blacksquare

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