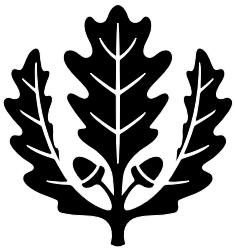

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On Job Rotation

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Abstract

A fundamental principle of economics with which Adam Smith begins The Wealth of Nations is the division of labor. Some firms, however, have been pursuing a practice called job rotation, which assigns each worker not to a single and specific task but to a set of several tasks among which he or she rotates with some frequency. We examine the practice of job rotation as a serious alternative to specialization, with three objectives. The first is to consider current and historical examples of job rotation, in addition to those in Japanese firms, in order to examine the variety of contexts in which job rotation has been practiced. Second, we develop a simple model of work organization in order to examine the cost and benefits of job rotation and to identify factors that make it the preferred organization of work. Extending the model in light of the available evidence, we critically examine the previous explanations of job rotation and identify some of the other, previously unnoticed, benefits such as reduced possibilities of shirking because of peer pressure. As a third objective, we evaluate the benefits of job rotation with respect to the organizational form of firms, particularly remuneration schemes and worker participation in decision making.

Journal of Economic Literature Classification: D20, J24, L23, O30

A fundamental principle of economics with which Adam Smith begins *The Wealth of Nations* is the division of labor. Specialization and the division of labor increase the productivity of workers by allowing them to concentrate on simple, narrowly defined tasks. Because greater division of labor generates higher productivity, firms generally have an incentive to increase the degree of specialization in their organization of work.

Not all firms appear to promote high degrees of specialization, however. For example, many Japanese firms are well-known for their practice of job rotation, which assigns each worker not to a single and specific task but to a set of several tasks among which he or she rotates with some frequency[1]. This practice clearly limits the degree of specialization, suggesting the possibility that the rotation of jobs produces certain benefits that outweigh lost productivity from reduced specialization. In fact, job rotation is generally identified to be so beneficial to have contributed greatly to the successes of Japanese firms. For example, in an influential study, Ouchi [1981] identifies non-specialized career paths as one of the fundamental properties of Japanese firms from which American firms can learn, and he details blueprints for implementing what he calls a "Type Z Organization." There is also evidence that some American firms have started to experiment with job rotation as one of the innovative transformations of the workplace (Appelbaum and Batt [1994], Osterman [1994]).

This paper develops a simple model of work organization to formalize the cost and benefits of job rotation and to identify factors that affect a firm's choice of job rotation over specialization, and workers' self-selection between firms with and without rotation. We use the model to explain two stylized facts about firms that have practiced job rotation. The first is that job rotation typically appears as a component of a bundle of attributes that also includes lifetime

tenure, worker-participation in decision making, and distribution schemes that include some form of profit sharing. Consistent with recent research that stresses complementarities among work policies[2], we argue that firms possessing these additional attributes receive a distinct set of benefits from job rotation, making them more likely than other firms to adopt job rotation in the workplace. As a second stylized fact, job rotating firms tend to be innovative. We argue that innovations in these firms emerge as a consequence of job rotation by allowing workers to apply their knowledge of one task to the improvement of others.

Job Rotation

There are practices other than job rotation that also limit the degree of specialization of workers. In the traditional craft production, for example, each craftsman performs all the tasks necessary to produce the final product[3]. Between the extremes of such total lack of specialization and complete specialization, one can find a variety of (actual or proposed) modes of organizing production, such as job enlargement, that assign a worker to a range of tasks that cover a large portion of the overall production process[4]. Job rotation differs from these practices in that each worker is actually specialized in a single task at any point in time but periodically rotates across tasks over time.[5] Contrary to complete specialization, the worker is not specialized

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[1] See, for example, Ouchi [1981], Koike [1984], [1990], [1994].

[2] Kandel and Lazear [1992], Holmstrom and Milgrom [1994], Milgrom and Roberts [1990], [1995], Ichniowski, Shaw, and Prennushi [1997].

[3] See Leijonhufvud [1986] for a discussion of division of labor and a comparison of crafts and factory modes of production.

[4] See, for example, the discussion and further references in Mason [1982, 169-70].

[5] Mechanisms similar to job rotation have also been regularly used for training purposes. One of the methods of developing skills during the Industrial Revolution was a practice called migration, which involved rotating trainees among tasks within and among firms (More [1980,

in the same task at all times; and contrary to crafts production and job enlargement, he or she is not assigned to several tasks at the same time.

Perhaps the best known examples of job rotation can be seen in the case of Japanese firms. As Ouchi [1981, 32] notes, "lifelong job rotation holds true for all employees in many Japanese firms. An electrical engineer may go from circuit design to fabrication to assembly, a technician may work on a different machine or in a different division every few years, and all managers will rotate through all areas of the business." Based on case studies of various large steel plants, Koike [1984, 63-5] argues that job rotation was practiced in Japan as early as the late 1950s. Studies show that job rotation has become wide-spread in other Japanese industries as pursued regularly in, for example, some of the well-known companies such as Toyota (Monden [1983]). Possibly inspired by the economic success of Japanese firms, there has also been a growing interest in job rotation in the U. S. The literature aimed at managers features essays that promote job rotation, and recent research on work practices finds that many businesses have instituted workplace transformations that include some form of job rotation[6].

Perhaps less known is the practice of job rotation by communal firms. For example, job rotation was a regular practice during the nineteenth century in the organization of work in a prominent American religious communal movement called the United Society of Believers, commonly known as the Shakers, as revealed by the diaries and journals of many Shaker members (Andrews [1963, 108-12], Brewer [1986, 81]). Studying these sources, Andrews [1932, 31] notes that "[t]he daily journals kept by many a brother or sister testify to the variety of

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ch. 6]). Similarly, the training of medical students includes a system of periodic rotation among all specialties.

[6] See Farrant [1987], Hazzard, Mautz, and Wrightsman [1992], Osterman [1994], Capelli and Rogovsky [1994], and Pil and MacDuffie [1996].

chores and tasks which were often a part of the daily routine, and expressions of satisfaction or relief were common when the diarist was about to enter or leave some particular occupation in which a system of rotation of labor was practiced." Another well-known communal society, the Israeli *kibbutz*, has practiced job rotation for many decades (Helman [1988], Leibenstein [1989]).

Although these examples do not exhaust the list of organizations that have practiced job rotation, they help to highlight some of the commonalties among firms that have otherwise existed in entirely different times, places, and market structures. Among these commonalties, we view two as being the most important. The first is that in each of these firms job rotation has been a component of a number of "unconventional" attributes. For example, Japanese firms have been variously described as providing lifetime tenure, being labor-managed (or producers' co-op), or having a management philosophy of "employeeism" (McCormick and Marshall [1987], Miyazaki [1993]). Similarly, as communes, both the Shakers and the *kibbutzim* have pursued egalitarian principles in the ownership of property and the distribution of output. These examples seemingly show the sharp contrast in attributes between firms that practice job rotation and other conventional firms with specialized workers who have a traditional employer-employee relationship to the firm. The argument also finds support in Osterman's [1994, 177] survey of innovative work practices in U.S. manufacturing establishments, which found that, although only 11.7% of the establishments used only job rotation as a flexible practice, "among those establishments that engaged in at least one flexible work practice, 56.3% used job rotation." The evidence on the incidence of job rotation thus suggests that firms with certain attributes are more likely than conventional firms to practice job rotation.

The second commonality is that job rotating firms have been noted as innovative. For example, in trying to account for Japan's post-war economic success, Aoki and Rosenberg

[1989] emphasize the success of the Japanese firms in innovation and product development.[7] The Shakers are similarly known as having been both innovative and inventive (Williams [1957], White and Taylor [1904, ch. 17]). The same is true of the *kibbutz*.[8] In what follows we develop a simple model of work organization in order to begin an examination of the cost and benefits of job rotation and to explain these two stylized facts.

A Simple Model of Work Organization: Specialization versus Job Rotation

Previous explanations of job rotation emphasize various benefits to workers and firms. As a benefit to workers, job rotation is said to cater to the preferences of workers for a variety of tasks.[9] For example, referring to job rotation among the Shakers, Andrews [1963, 108, 112] mentions variety in work as being "a source of pleasure" and that "the frequent change of occupation precludes monotony." Campion, Cheraskin, and Stevens [1994, 1537] similarly find that job rotation yields such benefits to workers as satisfaction and stimulation.[10] As a benefit to firms, job rotation is said to improve a firm's ability to deal with change. For example, Koike [1984], [1990], [1994], who has contributed importantly to understanding the Japanese skill-

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[7] See also Goto and Odagiri [1997].

[8] See Don and Leviatan [1987, 51], Don [1977, 61] for specific examples. See also Near [1992] for examples of innovative activities in the history of the kibbutz movement. Studying kibbutzniks and the Hutterites in a comparative framework, van den Berghe and Peter [1988, 532-33] note job rotation and inventiveness as being common characteristics in both communes.

[9] As a similar preference-based explanation of job rotation, Mourdoukoutas and Roy [1994] note that the practice provides insurance against unemployment. Specifically, by increasing the range of a worker's skills, job rotation makes a worker more valuable to the firm and therefore less susceptible to layoff.

[10] Although not directly related to job rotation, consistent arguments can also be found in the literature on the effect of specialization on worker welfare. For example, narrowly defined jobs are said to be a source of worker alienation (Rosner and Putterman [1991]), to be irksome and create an unskilled work force (Leijonhufvud [1986]), and to increase fatigue and boredom (Rosen [1983]).

formation systems, argues that job rotation endows workers with wide skills that improve their capability to deal with unusual operations[11].

Although accurate, these observations do not provide a complete picture of job rotation. Taken as a whole, these benefits would imply that all firms and workers would prefer job rotation and that job rotation would dominate specialization as the equilibrium form of work organization. This contradicts, of course, the limited amount of job rotation observed in the world. There must therefore be a cost associated with job rotation, and job-rotating firms and workers must have distinct characteristics that make them more likely than others to prefer job rotation over specialization.

Cost of job rotation

To discuss the cost of job rotation, we begin by developing a simple model of the productive gains from specialization[12]. Specifically, we consider a standard production function that transforms two inputs, X_1 and X_2, into some output Y:

(1) $$Y = f(X_1,X_2).$$

We will refer to the inputs as "jobs" that must be performed in order to produce the output. Suppose the firm employs two (initially) identical workers, each of whom is capable of performing both jobs. Thus, in a two-period model, each worker would produce the same amount in the first period. By assuming that the workers are identical in their intrinsic skills, we focus on the effect of the organization of work on acquired skills. According to a well-known principle spelled out by Adam Smith, a specialized worker improves his or her skill over time by repetitively performing the same

[11] See also Aoki [1986], [1990].

task. The gain from specialization thus arises in the second period if workers remain in the same job for both periods. In that case, we assume that the workers can produce more in the second period. By contrast, if the workers switch jobs in the second period, then each produces the same output in the second period that his or her counterpart had produced in the first period. To capture this, we let Y^1 denote the total output in the first period, and Y^2_r and Y^2_s denote the output in the second period under rotation and specialization respectively. When workers rotate jobs in the second period, $Y^2_r = Y^1$; when they specialize and remain in the same job, $Y^2_s > Y^1$. Specialization thus yields greater output over the two periods by the amount $Y^2_s - Y^2_r$. This differential represents the cost of job rotation in terms of foregone output.

Job satisfaction

The foregoing suggests that a purposeful choice of job rotation must yield some benefit to offset the cost. As discussed above, an important benefit is that workers prefer to perform a variety of tasks than to specialize in a single task. We generalize this observation by suggesting that workers have preferences for all attributes of their jobs, including variety in tasks, the system of tenure, remuneration schemes, and participation in decision making. To examine the role of workers' preferences, suppose that workers have utility functions that depend on their labor income and their level of "job satisfaction" that depends on job attributes. For simplicity we assume that the utility function is additively separable between income and attributes, and that the utility of income is simply equal to income. Formally, the utility function becomes:

(2) $$U(I, A_1, A_2, \ldots A_n) = I + u(A_1, A_2, \ldots A_n),$$

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[12] Recent analyses of specialization include Rosen [1983], Pagano [1991], and Becker and Murphy [1992].

where I is income and A_j is the jth job attribute provided by the firm (A_j=1 if the attribute is present and 0 if it is not).

Consider first arguments about the workers' preference for variety in tasks. To focus on the utility gain from job rotation, suppose for now that A_1 is job rotation and that all other attributes are held constant across firms. We can thus write the utility gain from job rotation in a very simple manner. Specifically, the workers receive utility in the first period equal to their labor income only regardless of the organization or work, but in the second period, they receive a *utility premium* of $u(A_1) = u$ if they rotate to a new job. In the absence of rotation, they receive $u(0) = 0$. Thus, if I^t is a worker's labor income in period t, his lifetime utility is $U_s = I^1 + I_s^2$ if he specializes, and $U_r = I^1 + I_r^2 + u$ if he rotates[13]. Of course, the income in these two cases need not be the same since we have seen that second period output will be lower under job rotation.

Self-selection by workers into specialized and rotating jobs

Given the cost and utility gains from job rotation, we first examine the way workers self-select into specialized and rotating jobs. When the negative effect of specialization on worker welfare is taken into account, workers might prefer job rotation even though that might decrease their income. As Pagano [1991, 320] puts it, "narrow jobs, organised on the basis of [division of labor] principles, may well imply an increase in the disutility of work greater than the increase in utility due to the increase of the product of work obtained by an application of these principles."

To focus on the workers' choice of jobs, suppose that firms are competitive and that both rotating and specialized firms exist and make zero profits (the firms are thus indifferent between specialization and job rotation). Wages will thus vary by the firm type, so we let w_s be the wage

under specialization and w_r the wage under job rotation. In both cases, we assume that the wage is set at the start of the first period and remains the same over the two periods. Zero profit for a specialized firm implies:

$$Y^1 + Y^2_s = 4\, w_s, \text{ or}$$

$$w_s = (Y^1 + Y^2_s) / 4. \quad (3)$$

For a job rotating firm,

$$Y^1 + Y^2_r = 4\, w_r, \text{ or}$$

$$w_r = (Y^1 + Y^2_r)/ 4. \quad (4)$$

Thus, $w_s = w_r + (Y^2_s - Y^2_r)/4$, or

$$w_s > w_r.$$

That is, the rotating firm must pay a lower wage due to the lower level of output.

Suppose that workers in the economy are identical in all respects except for the utility gain from rotating, u. The two-period utility of a worker who specializes is thus $U_s = 2w_s$, whereas the two-period utility of a worker who rotates is $U_r = 2w_r + u$. A worker would choose job rotation over specialization if:

$$2w_r + u > 2w_s, \text{ or}$$

$$u > 2 (w_s - w_r). \quad (5)$$

Figure 1 should be about here

Figure 1 shows the way workers choose between a specialized and a rotating firm. The downward sloping line represents the (w, u) pairs that give equal utility to a worker in a rotating

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[13] We ignore discounting.

firm and a specialized firm paying w_s. In other words, it shows the minimum w_r, given w_s , that workers will accept at the rotating firm for different values of the utility premium from rotation, u. Given the zero profit values of w_s and w_r as defined in (3) and (4), $u^* = (Y^2_s - Y^2_r)/2$ thus defines the utility premium for the worker who is indifferent between specialization and job rotation. Workers with $u > u^*$ will choose to go to rotating firms, and those with $u < u^*$ will choose to specialize.

Wage determination and job rotation

We now turn to a firm's choice between specialization and job rotation. Consider first the case in which job rotation provides no productivity benefits to firms. In this case, a firm's decision to use job rotation will depend only on whether it has any control over the wage rate. To see this, suppose that firms are identical in all respects except in terms of whether they can control the wage rate. We consider two cases: in the first, the firm can set the wage rate (i.e., we relax the assumption of zero profit and perfect competition in the labor market), and in the second, the wage is fixed (i.e., outside of the firm's control because of a competitive labor market, minimum wage laws, strong unions, etc.).

When the firm can set the wage, it can pay a different wage depending on whether the workers specialize or rotate[14]. The return to the firm over the two periods equals total output net of the wage bill. The firm would choose job rotation if the return under rotation exceeds that under specialization, or if:

$$Y^1 + Y^2_r - 4w_r > Y^1 + Y^2_s - 4w_s \text{ , or}$$

$$(w_s - w_r) > (Y^2_r - Y^2_s)/4. \quad (6)$$

Thus, a firm will offer job rotation if it can lower the wage at least as much as the lost output. Combining this condition with (5) shows that job rotation is feasible if there exist at least some workers with $u \geq u^*$.

The conclusion is different when firms take the wage as given. Suppose, in particular, that the wage is set at w regardless of the organization of work. The return for the firm under specialization is now given by $R_s = Y^1 + Y^2_s - 4w$, and its return under rotation is given by $R_r = Y^1 + Y^2_r - 4w$. Since the wage bill is the same under both regimes and $Y^2_s > Y^2_r$, the firm will clearly prefer specialization.

The preceding model thus predicts that, when job rotation provides no productivity benefits, firms that can somehow vary the wage rate according to job types will be more likely to adopt job rotation as compared to those firms that cannot control the wage rate. A variety of factors can cause differences among firms in their control over the wage rate. One factor is the behavior of labor unions. If a strong labor union negotiates primarily on the basis of wages and disregards (or opposes) other job attributes, then the firm would not be able to offer job rotation. But if the labor union includes job descriptions as an important item of its agenda and is willing to accept lower wages in return, the firm-union negotiation might result in a package that includes lower wages and job rotation. Another factor is that a firm would not be able to offer job rotation if the required w_r falls below the minimum wage. Job rotation is not likely to be observed, therefore, for jobs with such low wages.

Examples of firms that can vary the wages rate and thus offer job rotation, even in the absence of productivity benefits, include monopsonies and profit sharing firms. In the former, the

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[14] We assume that the choice is made at the start of period one and cannot be changed later.

firm is able to lower the wage to extract the utility gain from workers with high u. In the latter, because each worker's wage depends directly on the firm's return, as long as utility gains exceed the reduction in wages, workers are able to automatically internalize both the utility gains and the cost of lower productivity associated with rotation.

The role of job attributes

We now introduce possible productivity benefits of job rotation in order to explain why job rotation is more likely to be observed among firms that possess certain (exogenously determined) attributes.[15] As discussed above, one of the stylized facts about job rotating firms is that they offer workers various combinations of attributes such as egalitarian distribution, lifetime tenure, and participation in decision making. Although it is important to know why some firms, and not others, possess such attributes, we consider the origins of these attributes as being outside the scope of our analysis. By taking a firm's attributes as exogenously determined, we focus on the implications of these attributes for the firm's choice between specialization and job rotation.[16] We argue that certain complementarities exist between job rotation and these attributes, because their coexistence provides both additional utility gains to some workers and also distinct productivity gains to firms as well. Put differently, these attributes increase the feasible range for job rotation and thus make firms that possess them more likely than others to adopt job rotation.

To see this, consider the feasible range for job rotation as defined by the conditions under which both firms and workers prefer job rotation over specialization. These conditions, given by (5) and (6) above, define the feasible range as:

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[15] We thank an anonymous referee for alerting us to this line of reasoning.

(7) $u > (Y^2_s - Y^2_r)/2 \equiv u^*$.

The left-hand side of the inequality is the utility gain from rotation, and the right-hand side is the gain in output per worker from specialization in the second period. Recall, however, that, to focus on the utility gains of job rotation, we have so far held all attributes other than job rotation to be constant across firms. We have also assumed that the only factor affecting the difference in output was the productivity gain from specialization caused by increased skill in the second period. A wider interpretation of (7) is possible by relaxing both assumptions. In particular, we generalize workers' utility to include other job attributes and consider other factors that can affect output in a more dynamic framework.

According to (7), any factor that increases the average u or decreases $Y^2_s - Y^2_r$ will increase the feasible range for rotation. Consider first factors that can affect u. To see the effect of job attributes on the feasible range for job rotation, start with the case in which firms offer only job rotation, as described by Figure 1. Suppose that initially u=u* for all workers, so that they are indifferent between the two types of firms. In that case it is easy to see that, if firms differ in terms of other attributes that they offer and workers differ in terms of their utility from *all* attributes, then a worker who might otherwise be indifferent between specialized and rotating firms might now join a rotating firm if that firm also offers an attribute that increases the worker's total utility. For example, an individual might join the *kibbutz* or the Shakers for the package of attributes that include, along with rotation, such things as egalitarian sharing and religious practice, even though the worker's utility from specialization and rotation might be the same in the absence of these attributes. Similarly, a Japanese worker might join a job rotating firm that also offers lifetime tenure

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[16] A more general model would look at the benefits of a constellation of attributes, rather than any one in isolation. We believe that our arguments would extend to this case.

for the same reason. Alternatively, workers whose utility would decrease with the addition of these attributes would join specialized firms. In general, the argument suggests that even if the utility of the equilibrium outcomes of specialization and job rotation might be the same, differences in preferences for other attributes might be enough to generate different outcomes. Workers would self-select into different firms on the basis of their utility from all of the attributes offered by each firm. As a result, firms who possess these attributes would be more likely than others to attract workers to rotating jobs.

This obviously raises the question of why firms that possess other attributes would also tend to offer job rotation. One reason is the existence of complementarities between job rotation and other attributes. For example, job rotation might simply be a means for satisfying workers' preferences for egalitarianism. Job rotation in the Israeli *kibbutz* is said to promote such things as fair allocation of tasks, especially undesirable ones, and to eliminate hierarchy by rotating both the "boring" and the managerial jobs among members (Helman [1988], Leibenstein [1989]). In such cases both attributes might naturally coexist independent of productivity considerations.

In addition, there could be productivity-related complementarities between job rotation and other attributes that increase the feasible range for job rotation by decreasing $Y^2_s - Y^2_r$. To see the productivity gains from job rotation in firms that possess other attributes, consider first the example of a profit-sharing firm. The distinct gains of job rotation in profit sharing firms might arise from the way it helps to solve incentive problems (that is, rotation might decrease governance costs, or X-inefficiency). Standard incentive theory suggests that when a firm distributes the cooperative efforts of workers according to rules that do not depend on individual contributions, the workers potentially have an incentive to shirk (Ellickson [1993, 1351]). Given this incentive, a rule such as equal sharing may be costly either because it would result in suboptimal levels of

effort, or because a costly external monitor would be needed to ensure optimal levels of effort. In either case, all else being equal, standard incentive theory would lead one to expect the return to be lower in profit sharing firms than in others[17].

Although recent literature has identified effective mechanisms to deal with this incentive problem, these mechanisms might well be more effective in profit sharing firms that choose job rotation than in those that choose specialization. For example, a recent literature has shown that peer pressure and mutual monitoring among workers can be effective in dealing with the incentive problem in profit-sharing organizations (Kandel and Lazear [1992]). [18] However, it may be that this sort of "participatory governance" (Ellickson [1993, 1349]) is less likely to be successful in firms with specialized workers. Although having a financial interest in the firm's performance can motivate mutual monitoring among profit-sharing workers, mutual monitoring also requires workers to know as much about the production process as about their own specialized tasks. Specifically, in order to be able to observe and evaluate each other's performance and output quality, workers need to be broadly familiar with all the tasks and the production process as a whole. Whereas the requirement can be met with costly training in specialized firms, job rotating firms incorporate such training into the work process itself. Because each worker performs all tasks, he or she knows, for example, the time required to complete each task and the expected quality of output. And, because all workers know this, they would both try to avoid shirking due to peer pressure, and also be able to

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[17] See Coşgel and Murray [1998] for a discussion and quantitative analysis of the comparative productivities of communal and conventional organizations.

[18] Although a well-known solution to the incentive problem is to introduce an external monitor as a third party, it is also well-known that this solution might fail for various reasons such as inadequate incentives on the part of the monitor (unless the latter were made the residual claimant (Alchian and Demsetz [1972]). Additionally, the monitor may not know enough about the production process to

notice immediately shirking by others when it does happen. In sum, the more knowledgeable the workers are of each other's jobs, the more effective would be the peer pressure in creating incentives in the firm. The complementarity between job rotation and mutual monitoring would thus decrease $Y^2_s - Y^2_r$ and consequently increase the feasible range for job rotation in profit-sharing firms.[19]

Consider next the case of a firm that offers permanent or "lifetime" employment. Ouchi [1981, 17] considers lifetime employment as the "most important characteristic of the Japanese organization," encompassing about thirty-five percent of Japan's work force. Other organizations, such as communes, partnerships, and universities, similarly offer lifetime employment to (at least some of) their workers. The complementarity between lifetime employment and job rotation can be seen in light of the problem of labor shortage, which these firms are more likely than others to face. Unlike a conventional specialized firm that can quickly replace workers through the market, firms that offer lifetime employment typically have to go through a long process of recruitment, screening, and initiation before a job applicant can become a permanent employee. A temporary labor shortage can result, therefore, when a worker unexpectedly leaves the firm because of an accident or death, or by joining another firm.

Job rotation complements lifetime employment by insuring a firm against the risk of temporary labor shortages. A firm with specialized workers and lifetime employment would face a high risk of temporary labor shortages and the consequent risk of production bottlenecks because of

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be able to observe workers' effort and to implement a scheme that would provide sufficient incentives to work hard (Minkler [1993]).

[19] A similar benefit of job rotation in helping to deal with the incentive problem is through the sense of belonging. Workers involved in job rotation feel more like members of a "team" that is collectively responsible for the overall quality of output. This sense of teamwork "generates peer

the delay in replacing workers from outside the firm and the difficulty that other workers of the firm would have in performing the specialized tasks of the departing workers. A firm that practices job rotation, on the other hand, can easily avoid the bottleneck by reassigning vacant task among remaining workers, because other workers would be equally capable of performing the task. This can also be seen in terms of the model developed above by interpreting it in a more dynamic framework. If the two workers become specialized in single tasks and one of them unexpectedly leaves the firm, the firm would have to halt production until a replacement can be found. But if they rotate jobs in the first two periods, in subsequent repetitions of the production cycle both workers will have acquired both skills. Thus, if one of the workers were to leave, the other worker can still continue production by performing both tasks consecutively. Although the total production would be reduced, the firm can still continue production. The argument is consistent with Koike's [1984], [1990], [1994] emphasis on the advantage of having multi-skilled workers that can respond to unexpected occurrences. By making workers multiskilled and more flexible, job rotation complements lifetime employment as an effective mechanism to respond to unexpected labor shortages.

Consider finally the case of a participatory firm. Job rotation also complements worker participation in decision making by improving the quality of worker input.[20] Successful collective management by the workers requires that they be knowledgeable about the way the firm as a whole operates. In a specialized firm, improving workers' knowledge would require each worker to go through a costly process of training. A job rotating firm, on the other hand, avoids the cost by incorporating training into the work process. Once again, job rotation

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pressure that helps enforce high levels of performance" without the need for external monitors (Capelli and Rogovsky [1994, 210]).

complements worker participation by making the workers better understand the entire production process and thus participate more effectively.

These examples suggest that the coexistence of job rotation with other attributes is more than a mere coincidence. In addition to the possibility of jointly helping to achieve an organizational objective, job rotation complements other attributes in ways that generate unique productivity gains to firms that possess these attributes. Because attributes can also provide additional utility gains that differ among workers, a process of self-selection allocates workers between specialized and rotating jobs on the basis of their preferences for all attributes offered by firms. Complementarities between job rotation and other attributes thus helps to explain why firms that possess these attributes are more likely than others to adopt job rotation and to attract workers to rotating jobs.

Innovation as an Unintended Consequence of Job Rotation

A benefit frequently attributed to job rotation is that it improves a firm's ability to respond to change. For example, Koike [1984], [1990], [1994] and Aoki [1986], [1990] emphasize the role of intellectual skills in Japanese firms in their ability to deal with unusual operations (changes and problems). This benefit derives primarily from the broad knowledge that workers acquire of the entire production process through rotation. In the same vein, Carmichael and MacLeod [1993, 143] note the conflict between the firm's desire to implement, and the workers' incentive to oppose (for fear of unemployment), new technologies and argue that "multiskilled workers will cooperate with labour-saving technical change in cases where singly skilled workers will not."

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[20] We thank an anonymous referee for this argument.

Once again, this multiskilling derives from job rotation and works to ensure that the workers support technical progress.

The evidence on job rotating firms, however, suggests a stronger relationship between job rotation and change. Job rotation can improve a firm's ability not only to respond to change but to generate it. As mentioned earlier, job rotating firms typically tend to be innovative. To explain this stylized fact, we argue that job rotation promotes innovations of a "systemic" sort--across the stages of production-- as an unintended consequence[21]. This too is largely a consequence of the broadening of workers' knowledge of the overall relationship among tasks, thereby promoting "process style" innovations that result in more efficient organization of tasks and lower production costs.

It is well-known that Smith and Marx noted specialization itself as being an impetus to certain types of inventiveness (Leijonhufvud [1986, 215]). For example, Smith [1976, vol. 1: 17] saw "the invention of a great number of machines" as being one of the three circumstances that caused productivity to increase under specialization. This can happen in one of two ways. First, by devoting sole attention to a specific task, specialized workers might be able to find out methods or tools to improve their productivity. Second, both Smith and Marx noted that invention itself becomes a specialized activity as some workers specialize in the peculiar trade of "philosophy or speculation". Whereas both types of inventiveness have been important historically, we argue that job rotation can also lead to innovations of a different sort that has been largely neglected in the literature. Aoki and Rosenberg [1989] see Japanese firms as exemplifying the productive

[21] See Langlois [1988] for a discussion of the systemic versus autonomous innovation and the relationship between economic change and the organization of firm, including the division of labor. See also Pagano [1991, 319] and Carmichael and MacLeod [1993, 144] for the relationship between division of labor and innovation.

benefits that can be achieved by this sort of worker-initiated innovation. Noting the success of Japanese firms in (process) innovation, they examine the characteristics of the R&D process and suggest the wide range of skills and responsibilities as one of the important factors. We generalize this observation to all job rotating firms and argue that, as workers participate in all stages of the production process, they are able to initiate innovations by carrying ideas from one task toward improving the methods or tools of another task or the whole production process.

The benefits of job rotation in terms of technological or process innovations can be examined more formally in the context of the model above. In that model, recall, specialization was assumed to improve the productivity of individual inputs, itself a form of innovation arising from increasing skill or efficiency *in particular tasks*. This was reflected by the fact that if workers remained in the same job for two periods, total output went up; but if they rotated tasks, output remained the same. That is, $Y^2_s > Y^2_r$. The preceding discussion suggests that job rotation sacrifices this task-specific skill of workers in favor of a greater knowledge of the overall production process, which can result in innovation in the process, or the *organization of tasks*. We can capture this by supposing that job rotation leads to a different production function that more efficiently combines (or organizes) the existing inputs. Specifically, suppose that if rotation is employed, then in the second period the production function $f(\cdot,\cdot)$ is replaced by the production function $g(\cdot,\cdot)$ as a result of an innovation, where output from g is greater than output from f for any combination of inputs; that is, $g(X_1,X_2) > f(X_1,X_2)$, for all X_1 and X_2.

In the presence of this sort of process innovation, there now exists a productive trade-off between specialization and rotation--whereas specialization in effect increases inputs over time, rotation yields a more efficient combination of the same quantity of inputs. The above argument

implies that $Y^2_s >< Y^2_r$, or that specialization may or may not yield higher second-period output than rotation, depending on the relative strengths of the two forms of innovation.

Note, however, that job rotation by itself may not guarantee innovation. Because this sort of innovation is worker-initiated, it requires that the firm provide the proper environment for the implementation of these ideas[22]. In particular, the firm must have an organizational structure that allows workers a degree of autonomy and participation in decision-making. The workers must have the right and independence to experiment with ideas and also the opportunity to share information and seek the implementation of ideas into reality. Otherwise, without a mechanism to incorporate worker input into the firm's choice of the organization of tasks, rotation of jobs and experimentation with ideas will not produce any innovations in the process. Explanations of the success of the Japanese firms in process innovation also confirm the importance of worker autonomy and participation. For example, in their discussion of the communications structure of Japanese firms, Aoki and Rosenberg [1989, 145] note that "the Japanese organisation may appear as a coalition of semi-autonomous component units rather than a coherent whole directed by the visible authority of the central office." Note that this provides yet another illustration of the productive complementarity between job rotation and other attributes like worker participation.

At the risk of stretching the argument too far, the general relationship between job rotation and change can be extended even to the level of inventions of machinery and products. All else being equal and assuming that the workers have the required technical expertise, a job rotating worker might be more likely to invent new machinery or products than a specialized worker, if the invention benefits from the knowledge of other tasks or the whole production process. That is, in

[22] It also requires that the workers have an incentive to reveal their ideas, which has been examined in detail by Carmichael and MacLeod [1993].

addition to being able to introduce innovations in the organization of tasks, job rotating workers might also be more likely to replace labor with machinery (or a machine with a better one) or introduce novel products.

The best support for this latter form of invention comes from Shaker history, which contains rich examples of their ingenuity and inventiveness. For example, the Shakers are credited with inventing the flat broom in 1798, the "tilt-back" chair (which received U. S. Patent No. 8771) in 1852, a certain type of water wheel (U. S. Patent No. 45,114) in 1864, and for improving the washing machine in 1811 (Williams [1957], White and Taylor [1904: ch. 17]). Shaker ingenuity and inventiveness is difficult to explain because inventiveness was not one of the criteria that the Shakers used in recruiting or selecting members, and these inventions did not happen during a specific, limited time period or by a certain group of inventive individuals to be attributed to exceptional circumstances. One possibility, therefore, is that they were the unintended result of Shaker job rotation. Anecdotal evidence from Shaker history provides some support to this argument. For example, an interesting story is told about the invention of the circular saw by Sister Sarah Babbitt of Harvard around 1812, who is said to have come up with the idea after noticing the lost motion with the old type of saw. Then, as White and Taylor [1904, 312] recount, "[m]aking a tin disk and notching it around the edge, she slipped it on the spindle of her spinning-wheel, tried it on a shingle and found it was a success. From this rude, tiny saw...came the circular saw of today." Although this story might be incorrect or distorted over time, it nevertheless points toward the possibility of applying the knowledge of operating a tool (spinning-wheel) in one task to inventing a new tool (circular saw) for another task. One can easily imagine other examples. For example, the Shaker worker who invented the flat broom may have thought of the idea while using the broom as a cleaner on his rotation, realizing that a flat (rather than a round) broom might work better. The

important thing here is that the idea would not have easily occurred to a worker in a conventional broom factory who did not actually use the broom extensively, or to a house-cleaner who had no access to work in a broom factory. The relationship between the Shaker job rotation and their renowned inventiveness, we suggest, might be more than a coincidence.

The suggested relationship between job rotation and inventions is merely speculative at this point, however, and it raises more questions than it answers. For example, further research is required into the details of Shaker job rotation and the way these inventions actually occurred in order to be able to establish the relationship with more convincing evidence. Even then, today's advanced technologies and associated tasks may be too sophisticated to generate inventions with the kinds of rotation examples given above. With these caveats in mind, we simply suggest that it is possible for appropriate job rotation to generate inventions by allowing workers to carry ideas from one task toward improving the process or products in another.

As a final comment on the general relationship between job rotation and change, we suggest a different but consistent interpretation of the foregoing argument. To the extent that a certain firm values one or another benefit of job rotation related to change, that firm might consider implementing job rotation in at least the applicable part of the work force in order to realize the desired benefits. Our discussion has so far considered a firm's choice of one or the other form of organization--either specialization or rotation. Obviously, however, mixtures of the two may yield a better outcome, depending on the strength of the two effects for different clusters of tasks or different production lines. For example, although the above argument took innovation primarily as a by-product of an existing practice of job rotation among all workers, it also implies that a firm, for example one that seeks continual innovation in a certain clusters of tasks, might consider instituting the practice only among the corresponding workers. Even though job rotation may not be

originated by worker preferences or the firm may not have a general objective (e.g., egalitarianism) of pursuing job rotation for its own sake, rotation of jobs among at least some (e.g., high-skilled, managerial) workers might be desirable as a way to facilitate innovation, if not for other benefits of rotation.

Conclusion

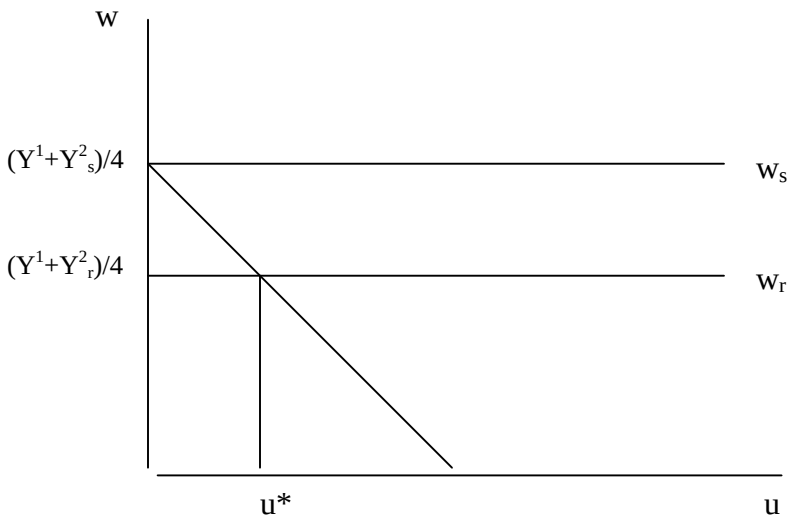
Rather than specialize in a single task, workers in some organizations rotate among several tasks with some frequency. Although job rotation has been noted in the context of large Japanese firms or as a recent innovative practice in American firms, economists have paid little attention to the practice, in deference to their emphasis on the gains from specialization. Our purpose in this paper has been to examine job rotation as a serious alternative to specialization. Considering the well-known arguments about the way specialization increases the productivity of workers, job rotation must produce certain benefits that outweigh lost productivity from reduced specialization. We therefore went on to develop a simple model of work organization in order to examine both utility benefits of rotation to workers and productive benefits to firms. We also identified factors that affect a firm's decision to adopt job rotation and workers' self-selection between firms with and without rotation.

The model helps to explain two stylized facts about job rotating firms. The first is that these firms typically offer workers various combinations of attributes, along with job rotation, such as egalitarian sharing, lifetime tenure, and participation in decision making. Various complementarities between job rotation and other attributes exist to provide workers with additional utility gains and firms with distinct productivity gains. For example, job rotation facilitates mutual monitoring in profit sharing firms, provides insurance against labor shortages in firms that offer

lifetime employment, and increases the quality of worker input in participatory firms. Because workers probably differ in terms of their preference for these attributes, a process of self selection allocates them between specialized and rotating firms according to their preferences for all attributes. Consequently, firms that possess these attributes become more likely than others to offer job rotation and attract workers. The second stylized fact is that job rotating firms have been noted as innovative. We argue that, as workers rotate among tasks, they are able to initiate innovations by applying ideas from one task toward improving the tools or methods of other tasks as an unintended consequence.

An important result of the analysis is that not all benefits of job rotation necessarily accrue to all types of firms. Similarly, not all workers will receive the same utility benefits from rotation, making them less willing to accept it in return for a possible wage cut. The emergence of rotation in equilibrium, therefore, requires a matching of firms and workers such that they enjoy mutual benefits from the practice.

Figure 1



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