Skill Development and the Distribution of Skill at an Iron and Steel Production Line

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This paper aims to address a case at a stainless steel plant (Plant B of Company A) and reveal the status of production skill that operators (general workers) have acquired at a production line. In particular, I analyzed the distribution of skill among operators and the influence of individual attributes such as a worker's age and academic background on the distribution. The section below summarizes the analysis results.

The analysis was conducted on evaluation findings of all operators (a total of 543 operators) working at Plant B. It was quantitatively confirmed through the skill level distribution that skill distribution is "inverted U-shaped type" centered on mid-level workers, mainly veteran workers. In addition, it was found through quantitative analysis of determining factors in skill level that the skill levels of a vast majority of the operators will be raised with increasing experience, and that a worker after some 25 years of service as an operator will be well qualified for problem-solving skill and maintenance operation. It was also suggested, through an examination of workers' attributes which affect their skill development, that a worker's intellectual level and willingness to improve skills are important for intellectual skill development.

I. The Purpose of This Study and Issues in Analysis

In this paper I address a case at a stainless steel plant (Plant B of Company A) and reveal the status of production skill that operators (general workers) have acquired at a production line.

In spite of some fluctuations in evaluations since the second half of the 1990s, the production system of Japanese corporations has generally received high evaluation marks as a source of competitiveness since the 1970s. Concretely speaking, a production control method known as Toyota's "Kanban," a strong product development capability supported by development projects and project managers in charge of the projects,[1] supplier systems serving as efficient long-lasting commerce networks,[2] and general workers' high level of skill and the way they work at a production line are among specific productions systems

[1] Fujimoto (1997) analyzed Toyota Motor Corporation's product development processes based on a theory of information and organizational ability. In particular, Fujimoto focused on the role of leaders who strongly coordinate and integrate internal and external projects for product development and called them as "heavyweight product managers."

[2] Asanuma (1997) pointed out that parts manufacturers who are generally called as subcontractors can be roughly classified into two types; "approved drawing manufacturers" who develop products by themselves after receiving rough specifications from outsourcers and "rental drawing manufacturers" who only manufacture products based on specifications provided by outsourcers. He also clarified the existence of rules that both outsourcers and their business partners can enjoy benefits brought about by cost reduction, technical innovation, etc.

evaluated so far.

Among the factors constituting the production system, this study focuses on general workers' (or operators') high level of skill. This is because the manufacturing department is somehow involved in production control and product development capability which are considered as a source of competitiveness, and the production line provides an important basis for the competitiveness, and because, among various factors constituting the production system, in particular, the way general workers work and their skill level are admired and criticized at the same time.

One of compelling theories on a high labor productivity of production lines is to evaluate highly-qualified general workers and their dedication. For example, factors appreciated by this kind of theory include a skill to respond flexibly to abnormalities or changes associated with production activities, which is defined as "intellectual skill" by Koike, "On the Job Training (OJT)" as a mechanism which forms such skill, and an ability-based grade system serving as an incentive. While they are sometimes regarded as production systems of Post-Fordism which has replaced Fordism (complete separation of concept and execution of production), at the same time, there has been deep-rooted criticism against general workers at a production line, claiming that they are rarely autonomous and are flexible only to the extent set by the management department in line with the principle of division of labor which lies at the bottom of Taylor System, though ordinary workers are supporting flexible production system by serving as multi-skilled workers.[3]

One of criticisms of Koike and others has argued that their studies lack specifics necessary for experimental studies. There may be two reasons for such criticisms; (i) the description is abstract out of consideration for the surveyed company, and (ii) since main method was interview survey, it was conducted to a limited extent, specific workplaces within the surveyed company. In this study, I have obtained data on the skill level of a total of 543 operators working for a plant from a company surveyed. There are following three issues to be clarified by analyzing the data:

- Skill distribution among operators working at an iron and steel production line
- Meaning of the skill distribution
- Effect of individual attributes such as age and academic background on skill development

[3] Suzuki (1994) reviewed and summarized previous studies. Suzuki pointed out that high productivity of Japanese manufacturing industry is caused by not the difference of manufacturing technologies or mechanization but the dedication of general workers at production lines. He discussed two explanations of factors contributing to the dedication of general workers; "job design" which unofficially encourages workers' initiative and "enforcement" by thorough labor control. He then concluded that a human resource management system at Japanese production lines should be understood as a unique integration of two management function aspects, enforcement to labor and encouragement of initiative, and arbitrariness which is customarily given to quality control circles and job allocation and incentive measures such as objectives management and suggestion systems have been sufficiently controlled from managerial viewpoints.

I would like to explain the reason why I have chosen the iron and steel industry for the study. The iron and steel industry, which has been serving as a key industry in Japan for a long time, is among one of sectors which have placed a particular emphasis on human resources management (personnel management), and accordingly, is a sector on which sufficient findings concerning labor issues have been already accumulated. For example, it has been frequently reported that the iron and steel sector has introduced and established a method of division of labor called "the line and staff system" in the course of production efficiency improvement, and the sector is an industry keen on quality control.[4] In addition, some changes during the 1990s have been reported in the division of roles between the administration and the manufacturing departments within a company which had been maintained so far by the line and staff system. There have been similar changes in the company surveyed in this study.[5]

Based on the above, it is reasonable to suppose that the iron and steel sector is a typical industry which will offer enough material for studying, based on accumulated research findings, skills and management at the production line, the scope of this study. I selected this sector as my case study partly because recently process industries such as the iron and steel industry have been seldom studied while assembly industries, including automakers and electronic manufacturers, have been frequently covered, and because the content and level required for operators may have changed due to revision of the traditional division of roles which took place during the 1990s.

I used the following procedures in this study. I conducted field research on details of the skill mainly through hearing investigation, using organization charts and manpower inventory data provided by the personnel department as basic data. I carried out a field hearing for the period from 1998 through 2004 on the subject of job content and the division of roles from engineers and operators working for the manufacturing department. I used findings from skill evaluation conducted at each workplace and personnel data for quantitatively analyzing individual attributes which can influence the skill distribution and skill level.

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[4] Nita (1988) analyzed the management-labor relation at workplaces, offices and entire company in Major Iron and Steel Manufacturer S in the 1970s and examined how workers and labor unions made comments in corporate decision making and decision execution processes and how their comments influenced corporate behaviors. The study focused on workers' commitments at workplaces such as "self control actions" and negotiation between labor and management concerning personnel rationalization, job transfers and productive structure adjustment. He concluded that workers' commitments in Japan have positive influences on economic performance, contributing to solution of labor-management problems and prevention of troubles resulting from responses to changing environments such as oil shocks.

[5] Tsuchiya (1996) reported processes of changing division of labor at a leading integrated steel manufacturer.

II. Earlier Studies on Skill

Koike argues that, through a number of his studies on the actual status of workers' skill, the competence at a Japanese production line lies in "intellectual skills" (Koike 1988, 1991, 1994, 1997; Koike and Inoki 1987; Koike, Chuma, and Ota 2001). Koike's "intellectual skills" are general workers' skill to flexibly respond to changes and abnormalities, which is mainly formed through a wide range of OJT.

In addition, Koike (2003) has also referred to the way roles are being shared among production workers, maintenance workers and engineers, i.e., the way labor is being divided. An important conclusion from his argument is that, assuming that workers actively engaged at a worksite have the intellectual level of someone who has finished compulsory education, (i) from the viewpoint of costs incurred in the division of labor and enhancement of workers' motivation, "integrated systems" where a direct worker is carrying out a wide range of duties is superior to "separated systems" where a direct worker carries out a limited range of duties, and that (ii) in the case of "an integrated system," the skill distribution is "inverted U-shaped type" in which there are many mid-level workers.

Many have already studied the concept of Koike's "intellectual skills," and among them, I would like to refer to studies of Asanuma and Ma both of which are closely related to the theme of this study.

Asanuma (1997) is widely known for having regarded the transaction between a parts manufacturer, generally known as "a subcontractor," and a manufacturer which places orders, as a long-lasting, efficient commercial network. Asanuma also points out some important facts and indications in the first part of his work, by analyzing the skill and career paths of blue-collar workers at a leading automaker, including those promoted to management positions.

More specifically, Asanuma finds out, through his analysis of career paths of blue-collar workers promoted to management positions, that experienced blue-collar workers are required to have "ability to teach others and leadership at a workplace, as well as 'intellectual skills'" (Asanuma 1997, 81). Ma (1994) surveys blue-collar workers' skill development at a plant producing brakes in a non-ferrous metal manufacturer for complementing and generalizing Asanuma's findings, and argues that blue-collar workers' skill development process is made up of three types of skill and a worker is required to master the three in the following order in a progressive manner: (i) "fundamental skills,"(ii) "integrative skills," ability formed based on fundamental skill to flexibly repond to changes and abnormalities, and (iii) "organizational skills," ability to train and supervise subordinates and to control an organization at a workplace, which is formed on the basis of both fundamental skill and integrative skill.

In this way, Asanuma and Ma develop arguments about the concept of "intellectual skills," yet some have criticized the concept. One of the most representative works against the concept is Nomura (1993, 2001). Due to limited space, I cannot introduce details of his works, yet, in summary, Nomura argues the following two points: (i) those who play roles in developing and maintaining 'intellectual skills' are not general workers but technical experts such as maintenance workers and (ii) he casts doubt on the validity of Koike's experimental studies. Nakamura (1996) also summarizes his findings from experimental studies conducted on some of workplaces with different types of technology as follows. It is confirmed, first of all, that every production line is involved in work associated with product development and production control more or less depending on the workplace. Such involvement is, however, integrated in a course specified by the administration of a company, and is not conducted autonomously by production workers on their own responsibility. That is, it is concluded that it is an "integration based on the separation" in a sense that workers are integrated with the concept based on "the separation of conception and execution," showing a different viewpoint from the division of roles, "integrated system" and "separated system" as Koike described.

These are the outline of Koike's concept of "intellectual skills" and earlier studies related to the theme of this study. While "intellectual skills" and "integrated systems" have provided effective analytical concepts for understanding the skill developed at a Japanese production line, there may be still some questions remained unanswered. For example, in studies prior to Koike (2001), workers surveyed were limited only to production workers. Accordingly, detailed role sharing between maintenance workers and production workers was not always clear. In addition, as Muramatsu (1996, 2002) has pointed out, additional discussion will be necessary with regard to various factors influencing whether one selects integrated systems or separated systems.[6] It is also desirable to conduct quantitative confirmation of the status of the skill level distribution in accordance with job experience, in particular, "inverted U-shaped" skill distribution. If "inverted U-shaped" distribution is confirmed, it would be necessary to consider the meaning of it in relation to the skill acquisition process which Asanuma and Ma have pointed out.

As for workers' intellectual level, one of requirements for the establishment of "intellectual skills," although Koike (1991) assumes it as the level at the end of compulsory education, some studies have revealed different viewpoints. For instance, according to Chatani report (1998), college-educated engineers are assigned to the site of thermal power plant to deal with highly-developed jobs accompanied with technical innovation, and Chuma (2002) points out that there is a possibility that leaders are shifted from operators to engineers at production lines for semiconductor exposure apparatus and other semiconductor devices in which advanced and widened knowledge is required for problem finding and solution. As these studies have suggested, there is also a possibility that workers' academic background is an important requirement for establishment of intellectual skills.

Among the issues listed above which need further discussion, I would like to analyze,

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[6] Muramatsu cited "attention to safety" as a reason why integrated systems have not been sufficiently introduced to quantity production lines.

in this study, quantitative confirmation and verification of the skill distribution, and possible influence of individual attributes on skill development.

III. Overview of Those Surveyed

1. Overview of Company A

Company A surveyed in this study is a specialized stainless steel manufacturer with about 1,100 employees. This study focuses on full-scale manufacturing Plant B, one of Company A's core plants, which smelts, rolls and finishes stainless steel. About 900 employees are working at Plant B, including about 540 operators and about 90 maintenance workers. In addition, about 300 employees from group businesses and affiliated companies are involved in a part of maintenance and production activities.

This study mainly covers the time in and after 1990. In the early 1990s, while Company A had to increase production due to active demand, it was strongly required to reduce costs, etc. to maintain its market share in order to oppose a major integrated steel manufacturer which made a full-scale entry into the manufacturing and sales of stainless steel. Plant B has taken measures to improve productivity since 1990 to drastically reduced costs. In this measures, blue-collar operators at the production line drastically reduced the frequency of equipment failure to improve the productivity by "extending their line of duty" such as undertaking maintenance work.

2. Production Organization

Those who directly or indirectly get involved in production activities are engineers, operators and maintenance workers. Engineers are assigned to production lines as chiefs or technical staff. Chiefs manage production, operation, personnel and safety within the section. Technical staff creates and takes measures aimed at improving productivity and quality and reducing costs under chiefs.

Operators consist of team leaders and non-rank-and-file workers. A team consists of a couple of operators and four teams are engaged in operation of equipment on three shifts around the clock. Each team leader has the authority to coordinate and direct operations. Team leaders are appointed from among workers and usually engaged in operation of equipment at the line like other workers. In other industries such as automobile one, the main job of team leaders is to manage the line and sometimes they are involved in practical operation as "reliefs" of sorts only if they have vacancies. In such a case, team leaders usually have to be distinguished from workers to make an analysis. However, in the case of Company A, since the main job of team leaders is to operate equipment, this study makes an analysis on skills of both team leaders and workers as operators.[7]

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[7] According to Asanuma (1997), in the case of Auto Manufacturer A (probably Toyota Motor Corporation) in 1982, "team leaders are not engaged in administrative tasks all day long unlike assis-

Table 1. Evaluation Items Concerning Operators' Skill Levels

Ability to operate			Ability to maintain equipment				Ability to improve with scientific methods
Operation	Quality control	Specific technical theory	Basic knowledge	Inspection and diagnosis	Failure analysis	Repair	-Multiple analysis - 4M analysis - PM analysis
Scale of 1 to 5	Scale of 1 to 5	Scale of 1 to 5	Scale of 1 to 5	Scale of 1 to 5	Scale of 1 to 5	Scale of 1 to 5	Scale of 1 to 5

Source: Author's self-made table based on data provided by Plant B of Company A.

Engineers direct operators through foremen. Foremen are appointed from among those who were team leaders, control a few lines under the supervision of chiefs and supervise and direct lines in their charge. Foremen, unlike team leaders, do not get involved in the operation of equipment. Therefore, foremen are not analyzed as operators.

IV. Relationship between Skill Distribution and Workers' Attributes

Skills required for operators at production lines are abilities to deal with problems on maintenance, equipment and quality, as well as operating equipment. Operators' ability evaluation by the supervisors, chiefs and foremen, was used as data to understand skill levels of individual operators.

The skill level evaluation on operators was carried out by their supervisors in October 1998 using common criteria. Evaluation items are divided into three main classes: "ability to operate" concerning skills of operating equipment; "ability to improve" using scientific methods required for problem solution such as IE method; and "ability to maintain equipment" concerning maintenance which is essential for improved productivity. As shown in Table 1, "ability to operate" and "ability to maintain" are further divided into more detailed items and rated on a scale of 1 (Poor) to 5 (Excellent).[8] Each evaluation item was rated in

tant managers or group leaders and spend around 50% of their working hours at production lines. Accordingly, they also serve as players within a team made up of ordinary workers, rather than as pure managers." (Asanuma 1997, 52). On the other hand, Auto Manufacturer B (probably Nissan Motor Co., Ltd.) had no position corresponding to a team leader of Company A in 1983. In Company B, there was an informal position which "serves as a leader of a small group made up of five to six workers at an assembly line, the smallest unit at a workplace, and was called as 'boshin'" (Asanuma 1997, 83). In this way, even among auto manufacturers, positions and titles are different depending on the company.

[8] Koike (2001) introduced an example that there are "work charts (*shigotohyo*)" describing workers' individual scope of job performance and performance standards at workplaces and such perform-

Table 2. Basic Statistics Concerning Operators' Skill Levels

Skill evaluation items	Operators (543 persons)			
	Average	Standard deviation	Minimum	Maximum
Ability to operate	3.44	1.04	1.0	5.0
Ability to improve	2.77	0.88	1.0	4.0
Ability to maintain equipment	3.26	1.01	1.0	5.0
Comprehensive ability	3.16	0.93	1.0	4.7

Source: Author's self-made table based on data provided by Plant B of Company A.
Note: "Comprehensive ability" stands for the average scores of above three abilities.

accordance with "skill criteria" which describe specific criteria. Since "skill criteria" are not open to the public, details cannot be explained here. As for "ability to operate," for example, 1, 2, 3, 4 and 5 stand for "unable," "able to operate with assistance," "normally able to operate without problem," "even able to deal with abnormalities" and "able to direct and instruct others" respectively. Similar detailed criteria are also provided in other items. As above, these criteria imply that operators are required to be ready for "unusual operations" such as dealing with changes and problems as well as execution of "usual operations" in which Koike describes.

Table 2 shows basic statistics concerning evaluation results. While scores of ability to operate and ability to maintain equipment are at the same level in the average and standard deviation, that of ability to improve are relatively smaller. The reason why scores of ability to improve are low may be because evaluation items for ability to improve include analytical methods, etc. which are rarely used by operators in their regular routines, while evaluation items for ability to operate and ability to maintain equipment are nearly skill levels of their regular routines. In fact, the coefficient of correlation between ability to operate and ability to maintain equipment is as high as 0.92, while the coefficients of correlation between ability to improve and ability to operate and between ability to improve and ability to maintain equipment are slightly lower, 0.82 and 0.85 respectively. Given the results above, it would be reasonable to consider only ability to operate and ability to maintain equipment as indices to measure skill levels for regular routines. However, there are many overlapped parts in three criteria; for example, both ability to operate and ability to maintain equipment include things to measure ability to improve. In addition, ability to improve includes "intel-

ances are regularly reviewed and used as basic data for merits evaluation. Skill evaluation in this example was conducted as one of productivity efforts and was frequently reviewed. Afterward, such evaluation has been conducted in a different way, and the revision has become less frequent. Skill evaluation results and employee evaluation results have never been directly linked.

lectual skills" in which Koike described, i.e., measures to evaluate knowledge of problem-solving methods which is necessary when dealing with changes and problems (unusual operations). Therefore, "comprehensive ability," the average score of the three criteria is used for the analysis below.

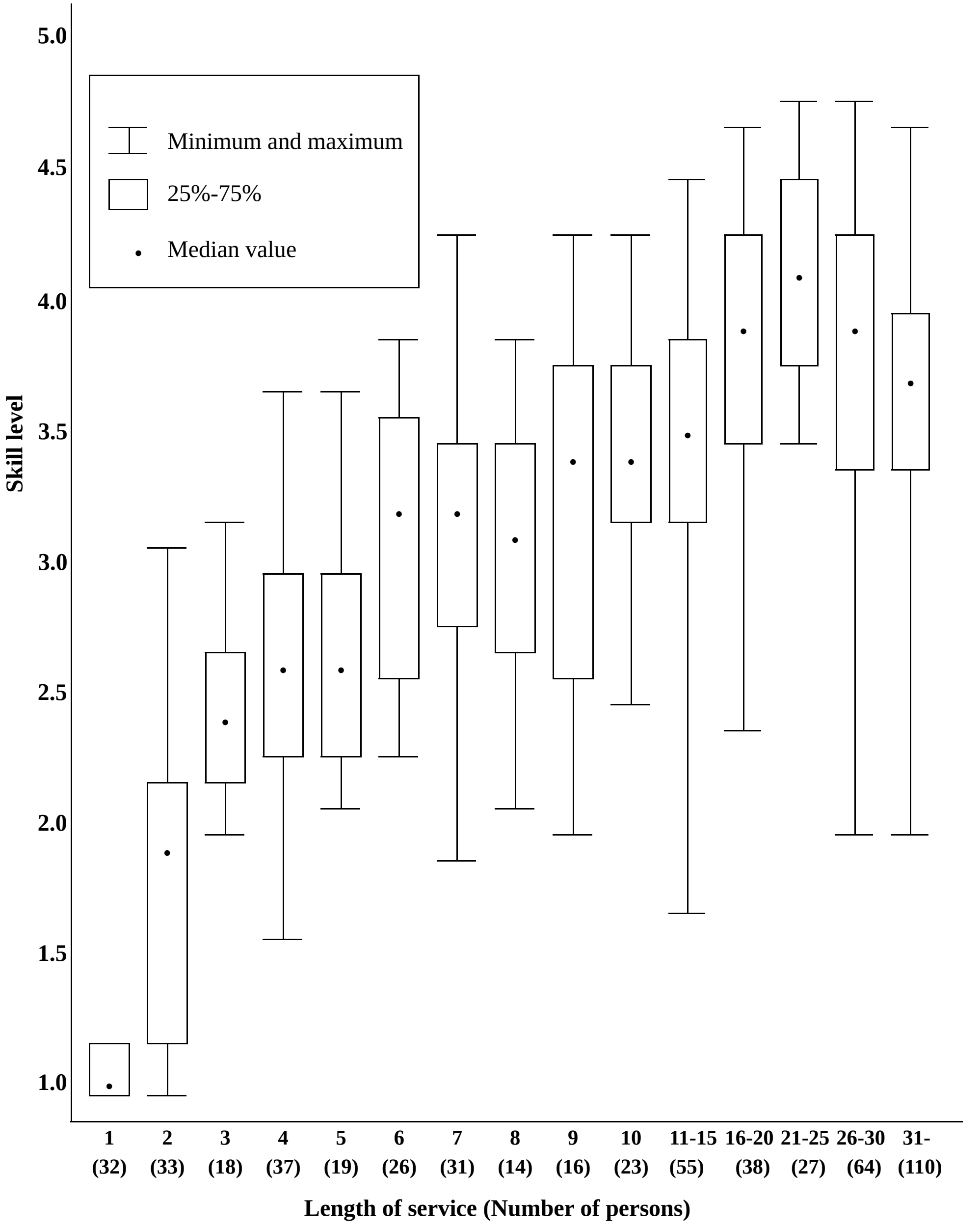
Figure 1 shows the relationship between the length of service and evaluation results of "comprehensive ability" in a boxplot. According to the figure, as a rough trend, a vast majority of operators' skill level is improved with the length of service. In addition, according to an interview survey on engineers and operators, around Level 4 of the evaluation results can be used as a measuring stick for the level enough to solve problems and maintain, and a majority of operators working for around 20 years have reached the level of 3.5 or higher.

As above, it can be said that a majority of operators at Plant B have improved their skill levels in proportion to years of experience. As mentioned above, Koike (2003) argues that at a production line in Japan, leaders dealing with problems on products and quality are mid-level general workers and the skill distribution is "inverted U-shaped" in which many mid-level workers have enough skill levels. These results are consistent with his argument.

However, factors which determine the skill level are not clarified by the distribution alone. Therefore, with more individual attributes on operators in mind, a multiple regression analysis was carried out to clarify determinants of skill levels. Explained variables for estimate are "skill level" indices used in previous analyses. Explanatory variables are, age, length of service, square of age, square of length of service, various qualification dummies, year of employment dummy and academic background dummy. Table 3 summarizes basic statistics of variables used in the estimate.

Of the total of 543 operators, 79% are persons without working experience in other companies; the remaining 21% are mid-career workers. 61% of operators are high school graduates and some senior operators are junior high school graduates. There are some operators who obtained a high school graduate certificate at the in-house training center. Some of those who recently joined the company as mid-career workers are college graduates and career college graduates. Since it is thought that such year of employment and academic background may have an effect on skill levels, those are also included in explanatory variables. Since there are a huge variety of combinations of academic background and year of employment in these samples, age does not always correspond to length of service. In addition, in order to check whether vocational qualifications such as crane operator license, dangerous object handler's license and engineering technician's license have an effect on skill levels or not, those dummy variables were added to explanatory valuables and the estimate was carried out with ordinary least square method (OLS) and ordered probit method.[9]

[9] Ordered probit analysis is suitable when explained variables are ordered category variables. Skill level indices which are explained variables in this analysis are averaged scores evaluated for each of three skill categories on a scale of 1 to 5. Accordingly, though they are considered as continuous quantity in an ordinary analysis, objections may be raised that the scale of 1 to 5 itself is not always based



Source: Author's self-made figure based on data of 543 operators provided by Plant B of Company A.
Note: Since the number of annual samples of 11 years or longer length of service is smaller, samples are collected by every five years for those periods.

Figure 1. Skill Level and the Length of Service

on variable quantities measured at regular intervals. For this reason, estimation with the ordered probit method was also carried out to be careful not to raise any objection. For ordered probit analysis, see Greene (2003, 736-40).

Table 3. Basic Statistics of Variables Used to Estimate Skills

(Sample size＝543)

Variable	Average (standard deviation)	Minimum	Maximum	Description
Skill level	3.16 (0.93)	1	4.7	Skill level Lowest=1, highest=5
Age	36.3 (13.2)	19	60	
Age^2	1,489.6 (1,035.5)	361	3,600	
Length of service	16.6 (12.9)	1	43	
Length of $service^2$	441.1 (521.6)	1	1,849	
Qualification (crane) dummy	0.831 (0.376)	0	1	Those having crane operator license=1 (451 persons), others = 0. Overhead crane operator license is essential for operators, however, acquisition of overhead crane operator license is relatively difficult and some have failed to obtain the license.
Qualification (dangerous object) dummy	0.433 (0.496)	0	1	Those having authorized dangerous object handling supervisor=1 (235 persons), others = 0. License of dangerous object handler is not essential for jobs, but many professional workers have tried to obtain the qualification.
Qualification (engineering technician) dummy	0.247 (0.432)	0	1	Those having engineering technician qualification = 1 (134 persons), others = 0. The qualification the corporation placed emphasis on during its productivity enhancement efforts. This qualification covers mechanical maintenance, oil pressure and electric maintenance.
Person without working experience in other companies dummy	0.786 (0.410)	0	1	Those who were under 20 years old when joining the company =1 (427 persons), others= 0.
Junior high school graduate dummy	0.133 (0.339)	0	1	Junior high school graduate = 1 (72 persons), others = 0. Operators' final academic background are divided into four: "junior high school graduate," "high school graduate," "graduate of in-house training centers" and "others (university or career college graduate)."
High school graduate dummy	0.606 (0.489)	0	1	Final academic background: high school graduate = 1 (329 persons) and others =0.
In-house training center dummy	0.230 (0.421)	0	1	Final academic background: graduate of in-house training centers =1 (125 persons), others = 0. Those graduating from in-house training centers are considered as excellent.

Table 4. Estimate Results on Determinative Factors for Skill Level (n=543)

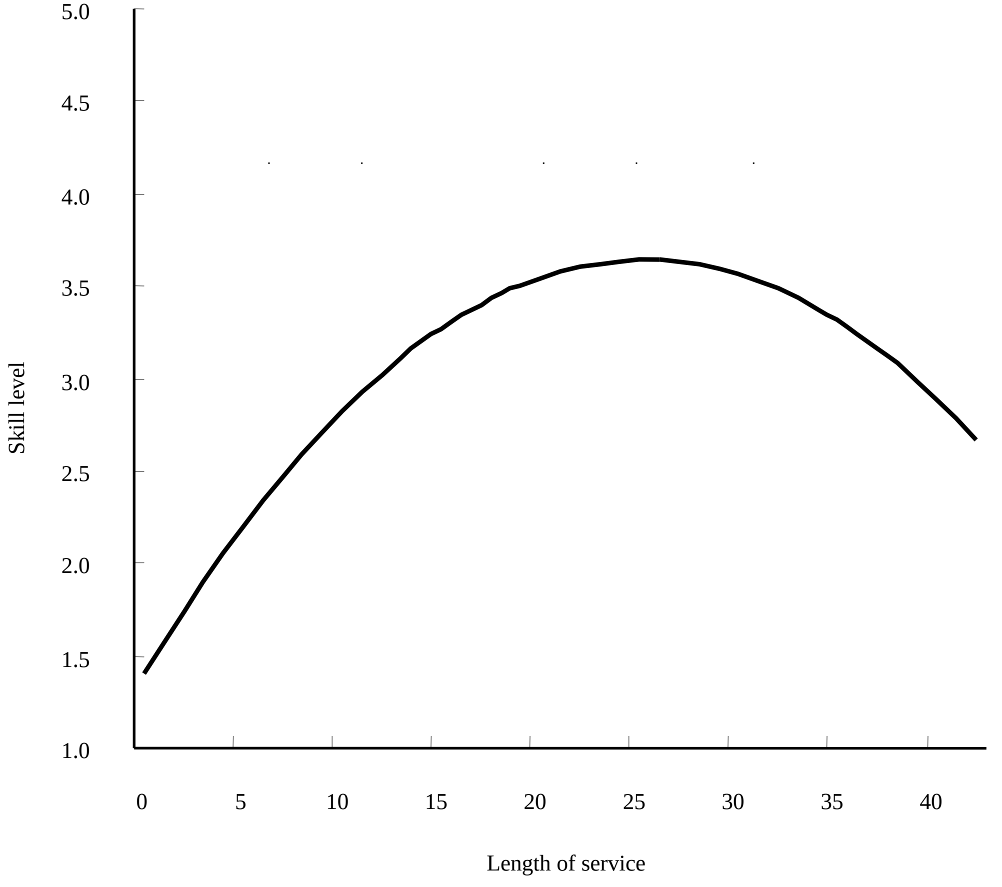
Explanatory Variable	OLS	Ordered Probit
Age	0.1479***	0.2273***
	(0.0274)	(0.0526)
Age^2	-0.0019***	-0.0029***
	(0.0003)	(0.0006)
Length of service	0.0976***	0.1775***
	(0.0181)	(0.0344)
Length of service^2	-0.0016***	-0.0028***
	(0.0004)	(0.0007)
Qualification (crane) dummy	0.4438***	0.7342***
	(0.0670)	(0.1329)
Qualification (dangerous object) dummy	0.0168	0.0647
	(0.0540)	(0.1017)
Qualification (engineering technician) dummy	0.1024	0.2719**
	(0.0656)	(0.1242)
Person without working experience in other companies dummy	-0.0741	-0.1597
	(0.0947)	(0.1782)
Junior high school graduate dummy	-0.0065	-0.0018
	(0.1652)	(0.3112)
High school graduate dummy	-0.0830	-0.1241
	(0.1473)	(0.2781)
In-house training center dummy	-0.0605	0.0224
	(0.1640)	(0.3094)
Constant term	-0.6442	
	(0.5059)	
R^2, Dummy R^2 (In the case of ordered probit)	0.6779	0.1506
R^2 with corrected degree of freedom	0.6712	

Note: Upper numeric numbers represent estimated coefficient values and lower numeric numbers in parentheses represent standard errors. Estimated thresholds between categories of explained variables in the ordered probit analysis were omitted. ***: p <1%, **: 1%< p <5%, *: 5%< p <10%.

Table 4 shows the estimate results. This paper mainly explains the result of OLS which is easy to interpret coefficient estimates. The value of determination coefficient (R^2) was explainable, 0.678. Individually significant variables were age, length of service, square of age, square of length of service and qualification (crane operator license) dummy.

In order to check the effect of age and length of service on skill levels, the relationship between length of service and skill levels was analyzed for standard high-school-educated operators who joined the company shortly after graduating from high schools (i.e., age minus length of service equals 18) as shown in Figure 2. The skill level becomes higher with years of experience until 25 years of service and goes down after that. This is an estimate based on the actual distribution and does not mean that individual skill level goes down after 25 years of service. The reason why such distribution is shown may be because operators with high skill level were promoted to foremen and went out of the sample.

A significant variable other than age and length of service was qualification (crane



Note: This was prepared on the basis of estimated results in Table 4.

Skill level$=$0.1479 × Age -0.0019× Age^2 + 0.0976 × Length of service - 0.0016 × Length of service^2 - 0.6442

This analysis is for high-school-educated standard workers who joined the company shortly after graduating from high schools, i.e., age minus length of service equals 18.

Figure 2. Estimated Result of Age and Length of Service

operator license) dummy. It has a significant effect accounting for 0.4 point in the range from 1 to 4.7 points of the actual skill level distribution which is an explained variable. On the other hand, other qualifications and academic background were not significant as well as small estimated coefficient values. However, according to the estimate results of the ordered probit analysis, qualification (engineering technician’s license) dummy was significant as well as explanatory variables which were significant in the case of OLS models.

Brief explanations of qualifications used as explanatory variables are as follows: Since overhead cranes are frequently used for transporting heavy goods such as products and parts at iron and steel production lines, overhead crane operator’s license is essential for anyone working there and operators are required to obtain the license. In order to obtain it, they must pass both written and practical examinations. In particular, there are four subjects in the written examination; “laws,” “dynamics,” “electronics” and “structure” and therefore a high-school graduate level of academic ability is required to pass the exam. Accordingly, they must study hard by themselves to obtain a crane operator license, and some operators cannot obtain it due to lack of motivation or ability.[10] Therefore, if an operator has not obtained an overhead crane operator’s license yet, his ability or motivation is lower than that of standard-level operator.

On the other hand, although it is desirable to obtain “dangerous object handler’s license” and “engineering technician’s license,” unlike overhead crane operator’s license, there is no direct obstacle to their jobs immediately even if they do not obtain those licenses. For this reason, operators voluntarily obtain “dangerous object handler’s license” as one of self-development training activities. As for engineering technician’s license, some selected operators were forced to take the exam as one of efforts to improve the productivity.[11] Therefore, it comes as no surprise that engineering technician’s license and skill level are positively correlated.

To sum up the estimate results, it was found that age and length of service have a significant effect on the skill level, significant qualification variables were “dangerous object handler’s license” and “engineering technician’s license (in the case of ordered probit)” only and variables on year of employment and academic background were not significant at all. Therefore, most of operators who have normal motivation and ability are able to improve their skills, and skill levels of those who are unable or unwilling to obtain a crane operator’s license (or engineering technician’s license) tend to be lower.

Based on above analysis, found facts on characteristics of skill distribution are as follows: most of operators’ skill levels become higher with years of experience and reach sufficient level around 25 years of service, i.e., “inverted U-shaped” skill distribution. However, there are a very few people whose skill levels are improved at a sluggish pace. There is no significant difference in year of employment or academic background. The significant difference is to have an overhead crane operator’s license which is essential for operators or not. If whether an operator has an overhead crane operator’s license or not is a proxy indi-

[10] In Japan, a worker who operates a crane which can hoist five tons or more must have a crane operator’s license by law (from April 2006, crane/derrick operator’s license). According to the Occupational Safety and Health Examination Board which conducts the examination for crane operator’s license as designated by the Minister of Health, Welfare and Labour, the pass rates for written and practical examinations were 56.9% and 48.3% respectively in FY2003.

[11] In Japan, any facility which stores or handles a certain amount of dangerous objects such as plants, gas stations and oil storage tanks must assign persons who have a national dangerous object handler’s license. According to the Japan Fire Engineering Qualification Center which is a designated examination board as provided by the Fire Service Act, the pass rate for class B dangerous object handler’s license was 40.1% in FY2002. According to the Japan Vocational Ability Development Association, the pass rates for the first-class and the second-class mechanical maintenance engineering technician’s licenses were 30.6% and 28.4% respectively in FY2003.

cator of a standard operator's ability and motivation, standard operator's skill level would be improved by accumulating experiences.

V. Summary of Analysis Results on Development of Required Skills and Their Distribution

In this paper, a quantitative analysis of skill distribution at an iron and steel production line was carried out and the effect of operators' individual attributes on their skill levels was analyzed. The analysis results are summarized as follows:

As for the distribution of skill levels which are almost synonymous with "intellectual skills" that Koike describes, it was quantitatively confirmed that it is an "inverted U-shaped" distribution centered on experienced workers. In addition, according to a quantitative analysis result on determinative factors for skill levels, skill levels of a vast majority of operators who have the standard level of ability and motivation become higher with years of experience and they reach Level 3.5 or higher which is nearly a measuring stick for the level of sufficiently solving problems and maintaining, Level 4, around 25 years of service. As for workers' attributes affecting skill development, academic background had very little effect on their skill levels. However, since having an overhead crane operator's license or not has a significant effect on it, it shows that workers' certain intellectual level and willingness to improve skills are important in order to develop intellectual skills.

Finally, the relationship between found facts and interpretation in this paper and previous studies is discussed. One of criticisms against Koike's "intellectual skills" is that his theory lacks specifics as an experimental study as Nomura (2001) argues. In this paper, it was quantitatively confirmed that the distribution of workers who have intellectual skills is "inverted U-shaped" distribution by using data on 543 operators of a plant of a single company. Hence, the analysis results in this study would play a role to support Koike's "intellectual skills."

More importantly, problems on the relationship between intellectual skills and ability-based grade system which were clarified by the analysis should be pointed out. The facts that the skills distribution is "inverted U-shaped type" and a majority of workers' skill levels are improved to a sufficient level around 25 years of service mean that skill level differences among workers rarely occur. On the other hand, in general, the rating disparity based on the ability-based grade system increases with the length of service. This probably means that there is another ability requirement evaluated by an employer other than intellectual skills. One of answers to this question may be in the indication of Asanuma and Ma in their preceding studies.

Asanuma argues that abilities such as leadership should be clearly distinguished from other skills in analyzing career of experienced blue-collar workers who are promoted to management positions. Ma argues that this is because the skill development process for blue-collar workers obtains "fundamental skills," "comprehensive skills" and "organizational skills" in this order progressively.

As above, according to Asanuma's and Ma's arguments, the widening rating disparity at later stages of career may be caused by the evaluation of management abilities such as leadership. However, Asanuma's and Ma's arguments are still disputible. For example, Ma claims that a worker obtains "fundamental skills," "comprehensive skills" and "organizational skills" in this order in the skill development process, but is it true? Although it is understandable that there is some continuity in terms of knowledge and acquisition processes between "fundamental skills" and "comprehensive skills," it remains questionable in terms of "organizational skills" which is quite different in skills and job content from other two skills. Another question is the relationship between blue-collar workers' promotion requirements and their skill levels. Ma (1994) argues that "an employee who has acquired both fundamental and comprehensive skills is in charge of training and supervision of his/her subordinates and is responsible for his/her entire unit organization" and "whether the employee has an ability to train or supervise his/her subordinates and control his/her site organization or not has a significant effect on the assessment and promotion." Accordingly, Ma seems to suppose an enrollment system that those who have acquired both "fundamental skills" and "comprehensive skills" are promoted to positions which requires "organizational skills" at first and after that they will be checked whether they have really acquired those skills.

It is pointed out that if promotion is carried out by the enrollment system, the person who was promoted to new position may not have skills required for the job. In order to avoid such risks, the skill development may be conducted so that "organizational skills" can be evaluated in early stages, i.e., "organizational skills" may be developed in tandem with "fundamental skills" and "comprehensive skills."

However, since there is little description on specifics of "organizational skills" and the development process in Asanuma's and Ma's studies, these questions are not answered. The reason why surveys corresponding to such questions or analysis issues of this study have not been conducted may be because "organizational skills" were simply seen as an extension of skills.

Based on facts found in this study and Asanuma's and Ma's arguments, the remained issue is to further discuss remained questions between intellectual skills and rating in an ability-based grade system.

References

Asanuma, Banri. 1997. *Nippon no kigyo soshiki: Kakushin-teki tekio on mekanizumu—choki torihiki kankei no kozo to kino* [Japanese corporate structure: A mechanism for innovative adaptation—structure and functions of long-lasing transactional relationship]. Tokyo: Toyo Keizai Shinposha.

Chatani, Motokuni. 1998. Sekitan karyoku hatsudensho ni okeru gijutu shinpo to unten rodo: Shokumu naiyo, kyaria, bungyo taisei no hikaku kenkyu [Technological progress at a cole power plant and operations labour]. *The Monthly Journal of the Japan Institute of Labour* 40, no. 8: 50-59.

Chuma, Hiroyuki. 2002. Monozukuri genba ni okeru mondai hakken kaiketu-gata jukuren: Nikyoku bunka keiko no haikei [The problem-finding & solving skilled production workshops: Tendency for polarization]. *The Japanese Journal of Labour Studies* 44, special issue: 4-14.

Fujimoto, Takahiro. 1997. *Seisan shisutemu no shinka-ron: Toyota jidosha ni miru soshiki noryoku to sohatsu purosesu* [Evolution theory of production systems: Organization ability and emergent processes at Toyota Motor Corporation]. Tokyo: Yuhikaku.

Greene, William H. 2003. *Econometric analysis*. 5th ed. Upper Saddle River, NJ: Prentice Hall.

Koike, Kazuo. 1988. *Understanding industrial relations in modern Japan*. Basingstoke, Angleterre: MacMillan.

———. 1991. *Shigoto no keizaigaku* [The economics of work]. Tokyo: Toyo Keizai Shinposha.

———. 1994. *Nippon no koyo shisutemu: Sono fuhensei to tsuyomi* [Japanese employment system: Its universality and advantages]. Tokyo: Toyo Keizai Shinposha.

———. 1997. *Human resource development*. Tokyo: Japan Institute of Labor.

———. 2003. Kyoso-ryoku wo sayu suru gino to sono keisei: Bunken sabei [Skill influencing competitiveness and skill development: Bibliographic survey]. *The Hosei University Economic Review* (Keieishirin) 36, no. 1:1-28.

Koike, Kazuo, and Takenori Inoki, ed. 1987. *Jinzai keisei no kokusai hikaku: Tonan ajia to Nippon* [Country-by-country comparison in human resources development: Southeast Asia and Japan]. Tokyo: Toyo Keizai Shinposha.

Koike, Kazuo, Hiroyuki Chuma, and Soichi Ota. 2001. *Monozukuri no gino: Jidosha sangyo no shokuba de* [Shop-floor production skill: At an automaker workplace]. Tokyo: Toyo Keizai Shinposha.

Ma, Jun. Nippon kigyo no naibu ni okeru gino keisei to insenthibu shisutemu: X-sha no jinteki shigen kanri no jirei kenkyu wo toshite [Skill development and incentive systems inside a Japanese corporation: Through a case study of human resources management at Company X]. *The Economic Review* (Keizaironso), no. 7 (supplementary volume):89-110.

Muramatsu, Kuramitsu. 1996. Ryosan shokuba ni okeru chiteki jukuren to togo bunri no keiko: dai-kigyo to chusho-kigyo no jirei kara [Intellectual skills and the directions of integration vs. separation among mass-production workshops]. *The Monthly Journal of the Japan Institute of Labour* 38, no. 6:2-11.

———. 2002. 1990 nen-dai ni okeru seisan shokuba ni kansuru kikitori shuho no hyoka [Evaluation of case studies on production workshops in the 1990s]. *The Japanese Journal of Labour Studies* 44, no. 2-3:47-55.

Nakamura, Keisuke. 1996. *Nippon no shokuba to seisan shisutemu* [Japanese workplaces and production systems]. Tokyo: University of Tokyo Press.

Nitta Michio. 1988. *Nippon no rodosha sanka* [Japanese workers' commitments]. Tokyo: University of Tokyo Press.

Nomura, Masami. 1993. *Jukuren to Bungyo: Nihon kigyo to teira shugi* [Mastership and the division of labor: Japanese corporations and Taylorism]. Tokyo: Ochanomizu Shobo.

———. 2001. *Chiteki jukuren-ron hihan: Koike Kazuo ni okeru riron to jissho* [Criticism of "intellectual skill theory": Koike Kazuo's theories and demonstration]. Kyoto: Minerva Shobo.

Suzuki, Yoshiji. 1994. *Nippon-teki seisan shisutemu to kigyo shakai* [Japanese-style production system and corporate environment]. Hokkaido: Hokkaido University Press.

Tsuchiya, Naoki. 1996. Tekkogyo ni okeru sagyo soshiki to jinzai keisei: Seizo, hozen no bungyo shisutemu no saihen [Work organizaton and skill formation in the Japanese steel industry]. *The Monthly Journal of the Japan Institute of Labour* 38, no. 12:37-50.