Working Smarter By Working Together: Connective Capital in the Workplace

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November 19, 2002

We thank the National Science Foundation and the Alfred P. Sloan Foundation for their generous support.

I. Introduction

"Capital consists in a great part of knowledge and organization."

-- Alfred Marshall, Principles of Economics

The idea that workers' personal knowledge and human capital are critical sources of productivity is a bedrock principle of economics. Less studied is the notion that organization is also an important source of productive capital. In this study, we use a unique, personally collected data base to investigate how a firm's human resource management (HRM) policies can create organizational capital by developing structures that promote productive exchange of knowledge among employees. In short, HRM practices can get employees to "work smarter" by getting them to work together more effectively. A central purpose of this paper is to extend the literature on the productivity effects of HRM practices by investigating precisely how innovative HRM practices might change workers' behavior to make them more productive.

We present a simple model that incorporates an organization's "connective capital" as an input into its production function, where we define connective capital as the stock of human capital that employees can access through their connections to other workers. Employees develop connective capital through communications links with other employees with the purpose of tapping into the knowledge of their co-workers as they seek to solve problems together. In Section 2, we develop this concept of connective capital and introduce the role of innovative HRM practices in producing different levels of this organizational capital. The main hypothesis from this section that we test in the empirical work is that HRM practices designed to promote greater employee involvement in decisions about plant operations increase connective capital by establishing a richer set of connections among workers. Section 3 describes the unique data set we have assembled on worker interactions in a carefully selected set of technologically comparable production lines in order to test this hypothesis. Section 4 presents estimates of the differences in the degree to which workers are inter-connected in production lines which are technologically equivalent but which operate under different HRM practices and with vastly different levels of productivity. Section 5 considers why less productive plants with traditional HRM practices do not adopt innovative HRM practices that promote more employee problem-solving and higher labor productivity.

We find that HRM practices aimed at promoting greater levels of employee involvement substantially increase interaction among employees, particularly among production workers, relative to more traditional HRM practices. Employees in plants with new HRM practices are working in environments with higher levels of connective capital, because the richer set of inter-worker linkages in these plants give workers access to the knowledge, ideas, and experience of a wide array of co-workers. Given the technological similarity of the production lines we investigate in this study, the high levels of connective capital appear to be an important reason for the productivity gains realized under new HRM practices.

II. A Model of the Productivity Effects of the Connective Capital

An emerging body of empirical research finds that, in many manufacturing industries, plants that adopt systems of "innovative" human resource management (HRM) practices enjoy higher levels of productivity than do plants that use more traditional HRM practices to organize work.[1] Typically, studies in this stream of research define innovative systems of HRM practices to include pay-for-performance plans such as gain-sharing or profit sharing, problem-solving teams, careful employee selection, broadly defined jobs, employment security, and labor-management communication procedures. Traditional systems of HRM practices are characterized by narrowly defined jobs, limited use of incentive pay, the use of layoffs, grievance procedures for channeling labor-management communications, and low levels of formal training.

These studies attempt to mimic an experiment that compares the productivity of a given production technology and workforce when it operates under an innovative HRM system versus a more traditional set of HRM practices. If the innovative HRM system is itself the cause of increased productivity for a given technology and workforce, then it

[1] Positive effects of innovative HRM systems on productivity have been documented in industry-specific studies for integrated steel mills (Ichniowski, Shaw and Prennushi, 1997), steel minimills (Boning, Ichniowski, and Shaw, 2000), automobile assembly (MacDuffie, 1995), textiles (Dunlop and Weil, 1997; Berg, Appelbaum, Bailey and Kalleberg, 1997), and in several cross-industry studies (Huselid, 1995; and Black and Lynch, 1997). For reviews, see Ichniowski and Shaw (2002) and Ichniowski, Kochan, Levine, Olson,and Strauss (1997).

stands to reason that these HRM practices promote more productive work behavior. Workers must be doing their jobs differently. Therefore, identification of real differences in the way work is done across technologically comparable production lines that operate under innovative and traditional HRM systems would provide additional evidence to help corroborate a causal link between innovative HRM practices and higher productivity.

In Ichniowski, Shaw and Prennushi (1997), we take great care to study the relationship between HRM practices and productivity within a technologically homogeneous sample – a set of steel finishing lines. The homogeneity of this sample together with the battery of econometric tests in that study provide strong support for the conclusion that the innovative HRM practices are themselves a cause of the improved performance. Furthermore, in that study's sample of steel finishing lines, we estimate productivity differences of about seven percentage points between lines with innovative and traditional HRM systems. Every percentage point increase in that study's productivity metric contributes an additional $360,000 per year to the line's operating profits – a figure that far exceeds any reasonable estimates of the costs of the HRM practices (Ichniowski, Shaw and Prennushi, 1997, 300-304). In this study, we re-examine production lines from this sample for which we have already established significant HRM-induced productivity differentials, and investigate differences in worker behavior under the different HRM systems.

This section presents a model that is based on two main propositions that motivate the empirical work to follow. First, worker and plant productivity increase not only through increases in individual-level human capital, but also through increases in the "connective capital" in the workplace – the stock of human capital that is created through worker interactions that allow knowledge sharing among co-workers. Second, innovative HRM practices increase this productive "connective capital" by promoting a richer set of connections among co-workers.

2.1. The Effect of Connective Capital on Plant Productivity

To formalize the first of these two propositions, begin with a general production function with labor (L) and capital (K) inputs:

(1) $Q = f(L,K)$

L is a function of the human capital of the workforce, HC^L:[2]

(2) $L = g(HC^L)$, with $g' > 0$.

HC^L in turn is specified according to the following equations:

(3) $AHC_i = \gamma (HC_i , \sum_{j \neq i} CC_{ij} HC_j)$

(4) $AHC = \sum_i AHC_i$

(5) $HC^L = h(AHC)$, with $h' > 0$.

Parameters subscripted by *i* or *j* refer to workers, and parameters with subscripts suppressed refer to firm-level characteristics. AHC_i in (3) is the aggregate human capital available to worker *i*. It is a function of two terms. As in more conventional specifications, the first term in (3) measures worker *i*'s own skill and knowledge. The second term in (3) measures the human capital of other workers that worker *i* uses. CC_{ij} is a weight that measures the degree to which worker *i* has access to worker *j*'s human capital, with $1 \geq CC_{ij} \geq 0$. The vector of all CC_{ij} where $i \neq j$ is worker i's communication network for receiving human capital from co-workers. *We define the "connective capital for individual worker" as* $\Sigma CC_{ij} HC_j$, summed over all workers $i \neq j$. *The "connective capital of the workplace" is given by the entire set of off-diagonal* $CC_{ij}HC_j$ *elements* in the worker x worker matrix. AHC in (4) is the total of all workers' aggregate human capital for the firm. According to (5), increases in connective capital will raise the firm's productivity.[3]

This notion of connective capital is similar to the concept of "social capital." Nahapiet and Ghoshal (1998, 243) define social capital as "the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or a social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network." However, social capital is a not a precisely defined term with many competing definitions available

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[2] Because we will be focusing on differences in productivity in technologically comparable production processes, we assume that number of labor hours is comparable across observations and therefore is not included in the L function.

[3] The equation (1)-(4) model is analogous to models of the productivity effects of spillovers of R&D knowledge across firms in an industry. See for example Griliches (1979).

(see Manski, 2000, 13-14). Here, we define connective capital more specifically as human capital that workers share with other workers.

While more specific than the idea of social capital, connective capital shares many features with commonly held views about social capital. Connective capital is a group characteristic (i.e., a complete set of off-diagonal elements in a worker x worker matrix), yet determined by decisions of each individual in the group. There are positive externalities to connective capital – when a worker shares ideas and knowledge with another worker, it makes others more productive. Network effects are important in connective capital, since a worker who gets ideas from a co-worker can pass that information along to others in his or her set of contacts.

We introduce connective capital as a determinant of productivity, because it can play an important role in employee problem-solving efforts and continuous improvement activities. Employee problem-solving aimed at improving organizational performance emphasizes sharing of expertise and ideas among employees. For example, in the sample of steel finishing lines that we investigate in this study, a worker may observe a problem of deteriorating steel surface quality. But to identify the actual reason for this problem from among many possible sources and then address it, an employee can draw upon his own training and experience and may also tap into expertise and experience of others. The expertise of co-workers (HC_j's) and the connection between worker *i* and and his co-workers (CC_{ij}'s) together determine how much connective capital worker *i* has. Connective capital contributes to the overall human capital available to the worker. Tapping into the human capital of co-workers with different skills and experience can in turn promote better problem-solving by shop floor workers and improved performance for the organization. The central point here is that access to others' knowledge and skills can promote problem solving and therefore overall levels of productivity in the organization.[4]

[4] More elaborate specifications of equation (3) may reflect the positive effects of connective capital more accurately. For example, knowledge that worker i possesses may only add to productivity when it is combined with the ideas or perspectives of worker j. Here, HC_i and $CC_{ij}HC_j$ would have an interactive effect on productivity. For our purposes, we are concerned with making explicit the idea that $CC_{ij}HC_j$ adds to productivity.

2.2. The Worker's Decision to Participate by Sharing Knowledge with Co-Workers

The preceding section makes a simple argument – connective capital improves productivity. This proposition is in keeping with much of the existing economic literature on social capital which focuses on the effects of social capital on various economic outcomes (e.g., Knack and Keefer, 1997). Yet, if different forms of social capital have these effects, the reasons why social capital varies must also be considered. Glaeser, Laibson, and Sacerdote (2000) argue that in order to understand variation in social capital, social capital formation should be modeled as a collection of individual-level optimizing decisions. We follow this approach by modeling the amount of connective capital in a workplace as an outcome determined by optimizing decisions of each worker. While connective capital is a workplace-level characteristic (since it is the entire set of off-diagonal elements in the $CC_{ij}HC_j$ matrix), individual workers decide the value of the elements in that matrix.

A decision to "work together" in a participation or problem-solving effort involves decisions by two workers. One worker, Worker 'A,' decides to solicit information, or to "pick the brains" of a co-worker. This worker faces the costs of effort associated with contacting people and pulling co-workers together. The second worker, Worker 'B,' decides whether to share his human capital with the worker who wants to pick his brains. This worker faces different types of costs. Like the first worker, he faces the logistical costs of responding to the request for assistance, such as attending a meeting, or putting other work aside. In addition, another potentially important element of his costs is the sense of injustice if Worker A (who initiates the contact) gets more credit for solving the problem. Worker B who shares knowledge with A naturally wonders if the initiator A will in turn share knowledge with him when he faces a problem to solve in the future. Thus, problem-solving requires two workers to participate – the one making the request for assistance and the one sharing his knowledge – but we focus on the second worker B who makes the decision to share knowledge. His incentives are more interesting because they imply a role for reciprocal interactions between workers, or reciprocal sharing. And in some sense, the decision to share is the final decision of the two and reflects the decision of the worker who possesses the knowledge. Stated in general terms, worker *i*'s decision about how much of his knowledge to share with his co-workers is given by the value that worker i sets for CC_{ji} (which in turn determines $CC_{ji}HC_i$).[5] We refer to the value that worker i sets for CC_{ji} as worker i's "participation decision."

What then are the costs and benefits of sharing one's own human capital with others that the worker must weigh when making this participation decision? In their model of social capital formation, Glaeser, Laibson and Sacerdote treat an individual's decision as an investment decision with returns as a function of the amount of social capital outstanding. Individuals invest when the benefit stream exceeds the costs. Individuals invest less in social capital with age, since their time horizon shortens.

In the context of a workplace, it is particularly important to elucidate the benefits an employee would expect from investing in connective capital. To develop a more specific model of the employee's participation decision, we allow the model to reflect the following workplace characteristics. First, while sharing ideas and information is a valuable form of employee effort, management cannot contract on this individual effort. Only the employee knows if he or she is offering their best information and the impact of knowledge sharing on ultimate performance is not measurable. Second, output for the entire workplace can be measured even though the contribution of an individual's or team's problem solving effort to that final output cannot be easily determined. Third, because we are explicitly concerned with the issue of team problem solving where working together produces better results than working alone, the production function is not separable in employee effort. Finally, the model will allow for the possibility that one worker's participation decision can affect the decision of others since it is often argued that individuals invest in social capital when many others are also participating.

According to equations (1)-(5) above, the firm's output is a function of aggregate human capital in the workplace, Q = R(AHC). To simplify exposition, consider the case of a two-person workforce, so that:

$$(6)\quad Q = R\,(\delta_i\,(HC_i, CC_{ij}\,HC_j) + \delta_j\,(HC_j, CC_{ji}\,HC_i))$$

Each worker maximizes the net benefits from sharing and participating. Let the benefits of sharing be distributed equally between the workers. Following the structure of Kandel

[5] Throughout the model, the second subscript on the CC_{ji} term refers to the worker who shares his human capital and the first subscript in the pair is the worker who receives the knowledge and ideas.

and Lazear's partnership model (1992), worker *i*'s participation decision can be represented as:

$$(7) \quad \max_{CC_{ji}} \frac{Q}{2} - C_i\,(CC_{ji})$$

The C_i function in (7) determines worker *i*'s cost of participating, with C' > 0 and C'' > 0. For our context, rather than a partnership, consider this to be a situation where the firm is implementing a group incentive pay plan that shares output among workers.[6]

Worker *i* shares his human capital with worker *j* at a level of CC*ji* according to:

$$(8) \quad \frac{R'}{2} \cdot \frac{\partial \delta_j}{\partial(CC_{ji} HC_i)} . HC_i = \frac{\partial C_i}{\partial (CC_{ji})}$$

Worker *i* stops his participation once the marginal cost of this effort equals ½ of the marginal benefits to the firm, rather than when marginal costs are equal to full marginal benefits resulting from this worker's participation. As in the Kandel-Lazear (1992) partnership, the level of sharing implied by (8) will be suboptimal from the group's (firm's) perspective because the worker is only taking into account his share of benefits. Group incentive pay on its own does not solve the problem of "underprovision of participation" and this underprovision increases with the number of workers. Note also that the worker deciding whether to share knowledge (worker 'B' above) and the worker initiating the request for knowledge (worker 'A' above) both have equivalent problems of underprovision of effort due to the division of returns, so the solutions to address this problem apply to both types of workers.

What other HRM policies can be implemented to promote greater sharing of human capital among employees beyond the level attained under a group incentive pay plan? One possibility is to lower the costs of sharing. In the model as presented is careful employee selection. The firm can select workers for whom $\frac{\partial C_i}{\partial CC_{ji}}$ is small (e.g., workers who don't mind sharing credit for their individual ideas), or it can reduce the

[6] To simplify the exposition, we let Q in (7) represent the surplus from production available to workers.

logistical costs of employee interaction (e.g., email for employee communication). Other HRM policies that increase the impact of shared human capital on productivity (i.e., an increase in $\frac{\partial \delta_j}{\partial(CC_{ji}HC_i)}$) will also foster more participation. Training programs that school workers on effective communication and brainstorming methods should therefore stimulate employee participation. Job rotation policies that allow workers to understand how one job on a production line affects another should also generate ideas for how the line might operate better.

To identify still other HRM practices that can increase employee participation beyond the level that a group incentive pay plan could generate on its own, introduce a Kandel-Lazear (1992) "peer pressure" function (P) into the employee's maximization decision. The peer pressure costs that worker i feels from worker j depends on how much worker i shares with worker j, or $P_{ij} = P_{ij}(CC_{ji})$. Unlike conventional cost-of-effort functions in which employee's costs rise with effort, peer pressure costs decline with effort ($\frac{\partial P_{ij}}{\partial CC_{ji}} < 0$). A worker can reduce the peer pressure from other workers by sharing more of his own human capital and participating more. With peer pressure, the employee's maximization decision becomes:

$$(9) \qquad \underset{C_{ji}}{\text{Max}} \quad \frac{Q}{2} - C_i(CC_{ji}) - P_{ij}(CC_{ji})$$

Kandel and Lazear (1992) consider different forms that P might take. For example, the peer pressure that worker i feels may be given by $P_{ij} = k*[(CC_{ij} + CC_{ji})/2 - CC_{ji}]$. $P_{ij} > 0$ when $CC_{ij} - CC_{ji} > 0$. When a worker's participation is below the average level of participation in the workplace – the workplace participation "norm" – co-workers pressure him to participate more. Regardless of the specific form of the peer pressure function, participation is greater with peer pressure than without since peer pressure costs decline with more participation.

Several HRM policies could increase employee participation in the presence of peer pressure. First, Kandel and Lazear (1992) suggest that the establishment of workplace norms, or a culture of participation, through up-front orientation can again be important. They argue that "… parents instill a sense of guilt in their children by spending time teaching them right from wrong. Firms may attempt to do the same thing. Thus guilt is generated by a stock of capital that requires significant investment…. This means that more should be spent up front on indoctrinating workers when their actions are unobservable." When workers feel guilty for violating the norms, participation is maintained at higher levels even when this type of effort can not be measured.

When peer pressure exists, careful employee selection will increase participation and connective capital. In particular, Kandel and Lazear demonstrate that individuals who are unaffected by peer pressure will not self-sort out of this type of workplace. Therefore, recruiting and selection efforts that focus on personality traits (e.g., cooperative workers who enjoy team environments) will be needed to generate consistently high levels of connective capital.

In considering HRM practices thus far, we have focused only on the ways in< which HRM practices can make group-based incentives more effective, but have not addressed a key component of connective capital – connective capital involves reciprocal sharing expectations. There are likely to be other HRM policies that can promote participation by encouraging reciprocity among workers. If CC_{ij} (worker *j*'s decision to share knowledge with worker *i*) is impacted positively by CC_{ji} (worker *i*'s decision to share with person *j*), then $CC_{ij} = f_j(CC_{ji})$, where $f_j' > 0$. Then, worker *i*'s decision becomes:

(10) $$R'\left(\frac{\partial \delta_j}{\partial(CC_{ji}HC_i)}.HC_i + \frac{\partial \delta_i}{\partial(CC_{ij}HC_j)}.HC_j.\,f_j'\right) = \frac{\partial C_i}{\partial CC_{ji}}$$

The worker now shares more when he expects the other worker to reciprocate and share in return. His sharing increases his co-worker's human capital as before, but it will now also increase his total human capital (since the co-worker responds by sharing in return).

Over multiple periods, this type of reciprocity among workers may emerge naturally if they adopt Axelrod-type tit-for-tat strategies in their decisions to share knowledge with each other. HRM practices can also play a role. The firm can promote this behavior through up-front worker training to establish a norm of reciprocity among workers to help ensure that $CC_{ij} = f_j(CC_{ji})$. An effective team leader can also use the team problem solving meetings themselves to foster a mutual expectation of sharing among team members.

In sum, this section develops two main propositions. First, connective capital increases worker and firm productivity. Second, the sharing of human capital among workers that determines the amount of connective capital in a workplace ($\Sigma\Sigma CC_{ij}\ HC_j$) will be higher when management couples group incentives with other innovative work practices (HRM) to promote sharing, so that:

$$(11)\ \sum_{i} \sum_{i \neq j} CC_{ij}\, HC_j = \phi(\text{HRM})$$

Specific innovative HRM policies that promote knowledge sharing among workers and team problem-solving include training in problem solving methods, job rotation, up-front employee orientation about workplace norms, and careful employee selection.

Together, these two propositions map out a path model in which HRM practices increase connective capital, which in turn increases overall productivity. In Ichniowski, Shaw, and Prennushi (1997), we establish the link between the beginning and end of this chain – between innovative HRM practices and higher productivity. It remains an open question whether innovative HRM practices promote increased connective capital and more active transfer of expertise among production workers as suggested in (11). The empirical analysis to follow focuses on this question by analyzing differences in connective capital and information sharing among employees working under innovative and traditional HRM systems.

III. Sample and Data

The literature on information flows and communication among workers has largely been theoretical.[7] To study empirically the differences in information sharing and connections among workers across workplaces with traditional and innovative HRM systems, one needs to assemble data worker interactions in technologically comparable workplaces with different human resource management (HRM) practices. We therefore

[7] See for example, Bolton and Dewatripont (1994), Geanakoplos and Milgrom (1991) and the related literature on managerial span of control (e.g., Keren and Levhari, 1979).

take advantage of the extreme homogeneity of the production processes of the steel finishing lines that comprise the sample in our previous research on productivity and HRM practices (Ichniowski, Shaw and Prennushi, 1997).

3.1 The Production Process

Before describing the data we collected on employees' work relationships in these steel production lines, it is first necessary to consider the particular production process that we are studying to understand how workers can do their jobs more and less productively. The sample for this study comes from finishing lines in the integrated steel industry. In this production process, very thin sheets of steel are treated in some manner, such as coating or softening or stretching the steel. The sheets of steel are typically four feet wide, about 1/16 inch thick or less, and about a mile long, so the steel is stored in coils weighing about 12 tons each. To process it, the coil is loaded on to the entry end of the line and the end of the new coil is welded to the steel that is currently running in the line. The new coil unrolls as the strip is processed continuously through the line. Machinery on the line cleans, heats, stretches, or coats the steel, and finally the steel is recoiled and cut at the end of the line. It is a continuous process that is very capital intensive.

The productivity of these finishing lines can vary in a number of ways. The most important way is that if the line shuts down due to a "delay," the line reduces "uptime" and loses potential output often including the steel in the line. For example, delays occur if the steel has a surface quality problem requiring correction, or a tracking problem causing the edges to crumple. Coils that break in the line or mechanical failures in the rolling process also cause line delays. Productivity is also lower if the line is up and running but producing poor quality steel that cannot be sold to its intended customer—which is a loss in line "yield."

3.2 Site Selection and Site Visits

Our previous study on the effects of HRM practices on manufacturing performance was based on a sample of 36 steel finishing lines. To collect data on interactions among workers for a given production technology managed under different HRM systems, we carefully selected seven of these thirty-six lines that come from the high and low ends of the spectrum of HRM innovation. We conducted employee surveys at three lines that rank at the top level of HRM innovation. These lines have a full complement of innovative HRM practices that the previous section predicts will promote more participation and more connections among workers. All three of these lines have adopted the following practices: broadly defined jobs, problem-solving teams, a multi-step pre-hire screening process that orients workers about workplace culture, the use of several personality tests in employee selection, extensive skills training, training in team problem solving techniques, and group-based incentive pay as well as pay-for-knowledge plans. We refer to these three innovative-HRM lines as *involvement-oriented (IO) lines*.[8] We also completed employee surveys at four lines that are in the low range of the HRM spectrum. These production lines have adopted few innovative HRM practices, limited only to labor-management communication procedures, the establishment of a formal team policy, and, as is common in the industry, group incentive pay based on quality tons of steel produced on the line. We refer to these traditional-HRM lines as *control-oriented (CO) lines* because they are run with more managerial control and less emphasis on employee involvement.[9]

Based on our previous research, a reasonable estimate of the difference in the uptime productivity measure due to the differences in IO and CO HRM practices would be about five percentage points. The difference in the prime yield quality measure due to the differences in IO and CO HRM practices would be about nine percentage points. These differences amount to very large differences in operating income for the lines.[10] While we do not have the data necessary to replicate the productivity analyses of our

[8] The nature of the HRM systems at these sites in 1997-1998 is similar in all important respects to the HRM systems in place when we conducted visits to these sites for our previous study.

[9] In our previous study of steel finishing lines, some lines had no innovative HRM practices. We referred to these lines as having the "traditional HRM system." By 1997-1998, no line had this traditional system in place, either due to line closings or to traditional lines adopting some innovative HRM practices. The lines in the control-oriented group in this study include two lines that moved from the traditional system to the "communication system" in our previous study, and two that were part of the "communication system" during the entire time frame of our previous study. The communication system is characterized by procedures for labor-management communication outside the framework of the plant's grievance process, and by the adoption of a formal work team policy but with little employee involvement in teams. While the control-oriented lines in this study have made efforts to increase employee participation since the time of the visits for our previous study, these lines still have considerably fewer innovative practices than do the involvement-oriented lines.

[10] For the estimate of the uptime productivity difference between IO and CO lines, we use the difference in coefficients between HRM system 1 and HRM system 3 in the Table 4, column 2b model. Our estimate of the difference in prime yield quality performance between IO and CO lines comes from the difference in the coefficients on HRM system 1 and HRM system 3 in the table 6, column 2 model (Ichniowski, Shaw and Prennushi, 1997, 300-307).

previous study for the 1998 time period used in this study, the productivity and quality measures for these lines still show the same kinds of large performance differences in 1998 that were present for these IO and CO lines in our earlier research.

We conducted new visits to these steel finishing lines between May 1996 and May 1998. Initially, we spent about three weeks in one IO mill and three weeks in one CO mill observing the day-to-day activities and talking with production workers, supervisory staff, and managers about their jobs. During this period, we conducted pilot tests of data collection survey instruments. After these initial visits to two of the sites, we visited each mill site between June 1996 and October 1997 for about one week each. During these visits, we made more direct observations of the workers, conducted further interviews, and collected certain survey data. A final set of visits to each site was conducted between March 1998 and May 1998, with each visit lasting about three days.

3.3 Survey Instrument

During this last set of visits, we obtained data for a parsimonious set of questions from virtually all production workers, maintenance workers, supervisors, and managers who work on the lines. The analysis in this paper focuses on data from this focused survey. Appendix A shows a sample of the survey questionnaire.[11] The survey has three main features. First, it identifies a list of all personnel with responsibilities for running or managing the line or with other responsibilities related to the day-to-day activities of the production unit and the respondent employee indicates all co-workers with whom he communicates. Second, the survey asks employees to identify the topic area of the communications with other employees: operation-related issues, customer-related issues, and work routines. Third, respondents identify the frequency of their interaction with other workers for the various communication topics. The three categories are "daily", "weekly", or "monthly."

3.4 Workers Surveyed

From our site visits, we identified those workers with responsibilities for the finishing line. These employees included line operators on four different crews, maintenance workers, foremen or team leaders, production managers, and staff and other support personnel. We administered the survey to all of these workers.

Exact counts of workers per line are difficult to calculate for one mill site in this study because it operates multiple finishing lines at a common site, and some managers, maintenance employees, and support staff are shared across these lines. Excluding lines from the mill with multiple lines, there are typically about 90 workers per line, ranging from 87 to 118 workers. The number of blue-collar workers – operators and maintenance workers – ranges from 47 to 51 workers across most lines, but in one line, the number of production and maintenance employees is 72 workers due to the high number of maintenance workers there. Samples in regression analyses below include responses for up to 642 employees across the seven lines.

IV. Empirical Estimates of Connective Capital in IO and CO Production Lines

In the empirical work to follow, we examine differences in organizations' and workers' investments in connective capital. The primary hypothesis, focusing on differences in organizations' investments, is that firms with innovative HRM practices (IO lines) have higher levels of connective capital. After presenting results substantiating this hypothesis, we turn to other questions concerning the individual decision to invest in connective capital and examine the relationship between an individual's connective capital and measures of personal human capital and wages. We also examine alternative definitions of connective capital. Finally, we address the question of why all firms do not invest in high levels of connective capital by adopting innovative HRM practices if connective capital is an important source of increased organizational productivity.

4.1. Values of Connective Capital and Human Capital

The definition of aggregate human capital in equation (3) suggests that it is easy to develop proxies for individual values of connective capital using the data we collected on connections among workers. Referring to equation (3), aggregate human capital is the combination of individuals' personal human capital, $AHC_i = \gamma\ (HC_i,\ \Sigma CC_{ij}\ HC_j\ )$. Connective capital for worker i is $\Sigma CC_{ij}\, HC_j$ for all $i \neq j$.

The first element of AHC reflects workers' personal levels of human capital. Traditional human capital measures for these workforces show that IO and CO lines have equally educated and experienced workforces. Measured by average years of education of the workforce, the CO and IO lines have nearly identical amounts—the mean education levels are 13.26 and 13.22, respectively (see column 1 of Table 1). There is a very slight difference in the distribution: the IO lines have a slightly higher variance to education, with more having only a high school degree, and more having a college degree. Measured by years of tenure at the work site, the CO lines have slightly more human capital—mean tenure levels are 13.67 and 11.84 respectively (column 2). The primary difference lies in the upper tail, since the CO lines have a set of considerably older workers with tenure greater than twenty years. We suspect that at these very high levels of tenure, small differences are not likely to be very indicative of skill differences in the workforce. The conclusion is clear: *the IO lines and CO lines have equivalent amounts of basic human capital in their workforces,* when human capital is measured by the traditional variables of education and tenure.

Looking at the second element of AHC—the level of connective capital of the workforce—we find that the IO lines have much greater amounts of connective capital than do the CO lines. In equation (3) above, the connective capital measure for each worker is calculated as the sum of the human capital of all the people with whom the worker is connected: connective capital = $\Sigma CC_{ij} HC_{j,}$, where the human capital of others ($HC_{j,}$) can be measured as their years of education (as in column 3 of Table 1) or their years of tenure (column 4). The average individual value of connective capital using years of education as the measure of HC_j (column 3) is nearly twice that for IO versus CO lines—665 versus 341, respectively. The average individual value of connective capital measured from tenure (column 4) is also much greater for IO versus CO lines—535 versus 299. Note also that the standard deviations of connective capital across individuals are smaller for the IO lines than the CO lines, indicating that most workers on IO lines have high levels of connective capital, whereas few workers on CO lines do, though there are some outliers on the CO lines who have higher values of CC.

Since the mean values of education and tenure are very similar between the IO and CO lines, it seems very likely that IO lines have high measures of CC because they communicate with more people, not because they communicate with better educated people. The last column of Table 1 shows mean values of CC_{ij} calculated for each person. CC_{ij} is the number of co-workers with whom worker i communicates (or the total number of "direct ties") normalized by the number of potential people with whom he might talk. The mean values of this individual measure of CC are very different for IO and CO lines. An IO worker communicates with 39% of all the other workers responsible for the line, while CO workers communicate with only 12%. The conclusion is clear: *the IO lines have nearly twice as much connective capital than do CO lines because workers on IO lines communicate more with fellow workers.* Given the evidence that it is the communications patterns that drive differences in the connective capital of IO and CO lines, we investigate who invests most in CC, and what drives the individual investment.

4.2. Illustrating Differences in Worker Connections Within and Between Work Crews

We provide preliminary evidence of dramatic differences that exist between IO and CO lines in the extent of connections among workers by presenting graphic illustrations of the ties that exist among workers in IO and CO lines. Figures 1a and 1b present diagrams of the connections within work crews for two IO lines, while Figures 1c and 1d present the corresponding diagrams for two CO lines. Figures 2a and 2b show inter-crew and inter-department diagrams for the two IO lines and Figures 2c and 2d present the corresponding diagrams of worker ties across crews and departments for the two CO lines.

In the Figure 1 and 2 diagrams, we are restricting our attention to only two of the three IO lines and two of the four CO lines in our sample, because these figures require an accurate identification of specific jobs of employees and the affiliation of workers to specific lines. For the one IO line not included in these figures, there are no clear distinctions between operator and maintenance employees because all production employees are part of a single job class and are cross-trained in production and maintenance skills. The two CO lines omitted from these figures operate in the same physical location at one mill and some managerial and maintenance employees are shared across two lines. For these two CO lines, it is difficult to assign some workers to specific lines. Therefore, this section contrasts the patterns of communication across two IO lines and two CO lines.[12] For the purpose of these illustrations, we focus on operations-related communications of any frequency (daily, weekly or monthly) but diagrams for other communication topics would show a similar pattern of extreme differences in the number of inter-worker communication ties between IO and CO lines.

The finishing lines in our sample run continuously, and allowing for days off during the week, four operator crews (A, B, C and D crews) are required to man the line on a continuous basis. In this section, we describe the work interactions within the A, B, C and D operator crews. Figure 1a and 1b show the four intra-crew networks for the two IO lines. Figures 1c and 1d show the corresponding four intra-crew networks for the two CO lines. Crew sizes range from 6 to 10 at these three sites. IO line 1 has the smallest crew sizes, typically 6 workers per crew, due to the particularly high level of cross training that workers receive at this line.

Figures 1a-1d show dramatic differences in the level of intra-crew communication between the two IO lines and the two CO lines. At IO line 1, the average crew member communicates about operations issues with 86% fellow crew members on the A crew, 78% on the B crew, 90% on the C crew, and 61% on the D crew. For IO line 2, the corresponding figures for the four crews are 76%, 86%, 70% and 73%. Over 90% of the operators on the two IO lines communicate with over 50% of their fellow crew members, and nearly all IO crew members communicate with 70% to 100% of employees on their own crews.

In contrast, on the CO lines, the extent of intra-crew interaction is much lower. On CO line 1, the A crew at the CO line has the highest level of intra-crew interaction of any crew at either of the CO lines at 44% of all possible intra-crew ties, but this is only about half the level of communication for the IO line crews. For the other three crews at CO line 1, an average crew member communicates with only 12% of his fellow crew members on the B crew, 19% on the C crew, and 16% on the D crew. On CO line 2, between 10% to 15% of all possible intra-crew ties exist in the four crews. Furthermore,

[12] Still, it is clear from the communication data for these lines that including these lines in the analysis would not change the conclusions we draw below. For example, the IO line not included in this section's analysis has very high levels of employee interaction. The interaction among employees who do maintenance work and operations work is especially high in this line even though we cannot distinguish which specific employees are maintenance workers and operators. Measures of degree centrality for the omitted CO lines are comparable to those of the two CO lines included in the analysis of this section.

out of 35 operators across the four crews at CO line 1, 20 workers communicate with either no other crew workers or one other crew worker *on his own crew*. Similarly, on CO line 2, 67% of the crew operators across the four crews communicate with two or fewer fellow crew members. *Employees on the CO lines are doing their own jobs on their own.*

We now examine the patterns of worker interactions on these four lines between operator crews, and between operator crews and the managers, foremen, and maintenance workers who staff the line. We calculate the average amount of interaction between any pair of the following eight employee groups: A crew, B crew, C crew, D crew, maintenance workers, foremen, line management, and other. We calculate this "average" level of inter-group interaction by first determining the number of possible worker-to-worker ties between any two groups. For example, the total number of possible two-person ties between the six-person A crew and the six-person B crew at IO line 1 is 36 ties. The actual number of two-person ties between the A and B crews divided by the 36 potential ties gives the percentage for the inter-group level of interaction for those two groups. We refer to this percentage as the "density of inter-group interactions."

We summarize the extent of inter-group interactions for the four finishing lines in Figures 2a-2d. Each network diagram shows eight nodes—one each for the four crews and for maintenance workers, foremen, management, and others. For ease of interpretation, we use the following cutoff points to indicate high, medium and low levels of inter-group interaction, and code these different levels of interaction with different lines. High levels of inter-group interaction (indicated with bold lines) exist when at least 60 percent of all possible two-person ties between the two groups exist. Medium levels of interaction (indicated with thin lines) mean that between 36% and 59% of all possible inter-group ties exist. Low levels of interaction (indicated with dashed lines) mean that no more than 35% of all possible ties inter-group ties exist.

Figures 2a-2d again show a very different pattern across the IO and CO lines with much higher levels of inter-group interaction in the two IO lines than in the CO line. Consistent with the higher levels of intra-crew interaction for IO lines shown in Figures 2a-d, there is again a much higher level of "horizontal" interaction across production and maintenance worker groups at the two IO lines than there is at the CO line. Ten possible departmental communications linkages exist among the five groups of blue-collar employees, where the five groups are the four operator crews and the maintenance crew. Therefore, the ten possible cells of linkages are the upper diagonal of the 5-by-5 matrix of communications between these groups. For CO line 1, the average of these ten cross-crew density percentages is 23.1%. These percentages range from a low of 9% to a high of 42%. For CO line 2, the average cross-department communication density for these five blue-collar worker groups is only 10%, ranging from a low of 0% to a high of only 19%. In contrast for the IO lines, the average cross-crew density among production and maintenance worker groups is 76.2% at IO line 1 and 71.6% at IO line 2. Across both IO lines, these cross-crew densities range from a low of 53% (or, 11 percentage points above the maximum cross-crew density at the CO line) to a high of 90%.

Maintenance workers tend to have higher interactions across crews than do the crew members themselves at CO line 1, but even here the extent of interaction of maintenance workers is, on average, only 27% across the four crews. The level of communication between maintenance workers and the four operator crews at CO line 2 is especially low, ranging from 0% to 9%. The density of inter-group interaction involving the maintenance group in the two IO lines is comparable to the levels of cross-crew interaction at those same lines – 77% on average at IO line 1, and 78% on average at IO line 2. *Horizontal communications, either among production workers on the same crew or among operators and maintenance workers on different crews is substantially higher in IO lines than in CO lines.*

The patterns of communication between the foremen/team leader or the manager groups and the various production and maintenance worker groups does not show the kinds of clear distinctions between the IO and CO lines that we found for the production workers. The average density of inter-group interactions between managers and the six other employee groups is actually higher in CO line 1 (52% on average across the six non-manager groups) than it is in either of the IO lines (42% in IO line 1 and 45% in IO line 2). At CO line 2, manager interaction with the six other employee groups is lower (or 21% on average).

The degree of foremen/team leader interaction with production and maintenance workers is relatively high at CO line 1 and the two IO lines. The density of inter-group interaction between foremen/team leaders and the five production and maintenance worker groups is: 61% at IO line 1, 78% at IO line 2, and 69% at CO line 1. This figure for communications between foremen and maintenance workers is substantially lower in CO line 2, or 5%. In sum, in our IO lines, we find much higher levels of inter-group interactions between crews of production and maintenance workers. We do not find striking differences in the communications patterns of managers between the two IO lines and one of the CO lines. However, one CO line is characterized by low levels of worker interactions within crews, across crews, and across employees in different positions.

4.3. Empirical Estimates of the Magnitude of Differences in Worker Connections

Figures 1a-d and 2a-d provide striking evidence of dramatically higher levels of worker connected-ness in IO than in CO lines. We now estimate the magnitude of the difference in connections among co-workers for different communication topics (i.e., customer-related, operations-related, and work routine topics) among workers in different positions (i.e., production and maintenance, foremen and team leaders, managers, and staff). We measure the extent of the CC_i links using a measure of communications networks from the social capital literature – "degree centrality." "Degree centrality" is the sum of all direct links from focal person i to all others. It is also connective capital in (3) when HC_j=1 for all j:

$$\text{Degree Centrality}_i = \sum_{j \neq i} CC_{ij} / N$$

where CC_{ij}=1 if worker i communicates directly with worker j, and the sum of communications is divided by N to control for the different sizes of the networks. Degree centrality is bounded between 0 and 1.

Table 2 summarizes these data on degree centrality using Tobit regressions that test for the significance of the differences in degree centrality across IO and CO lines. We estimate models as a double-sided Tobits with mass points at 0 and 1. The sample for the Table 2 regressions includes three observations per worker – one each for the survey questions asking about their communications on the topics of operations, customers, and work routines. We also have three measures of the strength of the ties based on their frequency – "strong" ties are daily communications; "weak" ties are monthly communications; and "all" ties are daily, weekly or monthly – as measured in the columns of Table 2.

As was evident in the figures and Table 1, IO lines have much greater numbers of direct contacts – on CO lines workers communicate with an average of 17% of all employees, but on IO lines this rises by 19 percentage points to 36% (column 1, after controlling for type of communications). Moreover, the increase in communications occurs across all jobs – among production workers, managers, staff, and foreman or team leaders – though the gains are greatest for team leaders relative to foremen as they increase their communications from about 13% to 46%. Looking only at the increase in daily communications (or strong ties), one finds that managers in IO and CO lines have similar numbers of daily communications.[13]

The evidence in Figures 1 and 2 and in Tables 1 and 2 provide clear support the study's central hypothesis that worker interactions are far more extensive in finishing lines with innovative HRM systems than in lines with more traditional work systems. *Connections among workers (which determine the* CC_{ij} *term from the section II model) are significantly and substantially higher in IO lines than in CO lines for all work-related topics of communication.*

4.4. The Individual Decision to Invest in Connective Capital

The model in section II describes the individual worker's decision to invest in connective capital. It argues that an organization's HRM policies can play a large role in overcoming workers' concerns that they will not benefit when they share their knowledge if other workers are not also participating or if workers do not combine their ideas in ways that improve productivity. The analysis above illustrates much more interaction among workers under the innovative HRM practices adopted by IO lines. The section II model also suggests several sources of variation in connective capital across workers. Some workers with more individual human capital may have better ideas for improving line performance and these workers may have more productive information to share. Even if monetary benefits are shared among all co-workers, the payoff from a very

[13] We also estimate regressions in which we omit observations in IO lines with very large numbers of ties to test whether the positive IO effect is driven by the higher communications for a subset of the workforce. Even eliminating these outliers in IO lines, we find that the IO effect is very positive for all groups of workers.

productive idea may still outweigh any costs of sharing for the individual. While the average level of connective capital varies across IO and CO lines with their different HRM policies, we can examine the extent to which human capital variation within lines is related to the variation in the number of ties that workers have.

The model also suggests there could be individual differences in the cost of investing. For example, workers could differ in the degree to which they feel guilt from not participating. Unfortunately, proxies for these individual differences (such as test scores in personality tests) are not available, and it is unlikely that standard human capital measures – age, education, and tenure – predict these kinds of individual differences. Our analysis of determinants of connective capital for individuals focuses on the relationship between the number of worker ties and his education and tenure at the line. At a minimum, these tests allow us to examine if workers' decisions reflect a conventional investment pattern with investments declining with age.

We also provide some suggestive evidence on the relationship between connective capital and wages. The section II model only allows for an organization-wide incentive pay plan, and these finishing lines all have a group incentive tied to tons of quality steel produced. Still, this group incentive pay is augmented by some individual pay, either through merit pay based on performance evaluations or through promotions. In this case, if connective capital is a form of investment that has can be rewarded on an individual basis, several standard predictions follow. Investment will rise with the length of the expected time horizon for returns and thus will rise with expected future tenure and will fall with age. Investment in connective will rise with education or tenure if problem-solving capabilities rise with these investments in tenure or education. Finally, if connective capital and sharing of ideas can be rewarded on an individual basis, greater investments (more participation and sharing) should produce higher wages or faster promotions. Even if such individual payouts for participation do exist, we can examine whether the shared monetary benefit to all workers in the IO lines (where participation is greater) tends to be concentrated among workers with the most inter-worker ties or if it shared as an average benefit to all IO workers regardless of the degree to which they share information with others.

Individual Investment in CC. As displayed in Table 3, the individual investment in CC rises modestly with tenure and with education, though the effects vary somewhat by occupation. Education raises daily communications among production workers (strong ties in column 2), with the positive affect of education peaking with fourteen years of education (see column 2, and note that education dummy variables confirm this effect). Education raises daily, weekly, and monthly communication for non-production workers, with the effects also peaking at fourteen years of education. The predicted effect of tenure on CC is theoretically ambiguous – though CC should rise with expected future tenure, it should decline with actual tenure as an age effect. In steel mills, workers rarely quit, thus there are few differences in expected future tenure. However, high actual tenure could signal declining future returns to investment. Empirically, the estimated effect of tenure is weakly positive. Finally, age has an unambiguously negative theoretical effect on CC, and the estimated effect is strongly negative for managers and staff, but approximately zero for production workers.

The Wage Returns to Investing in CC. Individual base wages will rise with CC if merit pay or promotions rise with CC. Wage data for workers on these lines are limited, because firms would not release wage data by name. We were able to obtain some wage data from two production lines. These data are limited to those with who are non-exempt workers (i.e., covered by the FLSA and thus managers are excluded). In addition, to protect confidentiality, the wage information is reported as a wage ratio—the individual wage divided the wage rate of the one highest paid foreman (on the CO line) or team leader (on the IO line). Thus, within-line wage ratio comparisons are meaningful comparisons of absolute pay differentials among workers, but across-line wage ratio comparisons are relative comparisons. After limiting the data to all those who are production workers and non-exempt support staff, we have 88 observations for these two lines. While this is a small sample, these workers are in many respects very homogeneous – they are the production workers who run one type of steel line and the secretaries and lower-level staff who support the line.

The results reveal that operators on IO lines have much higher relative wages than they do on CO lines—IO operators earn 24 percent more (column 2, Table 4). When the IO-line dummy is replaced by "Degree," this connective capital variable explains much of the wage variation explained by IO (column 3). That is, Degree measures the higher level of inter-worker communications on IO lines that explain the fact that the average worker on an IO line earns 76 percent of the pay of his team leader, while the average worker on a CO line earns only 52 percent of his foreman's pay.[14] Moreover, when IO and Degree are included in the same regression (column 4), Degree continues to offer some explanatory power: within lines, high communicators earn higher pay.

One explanation for the higher pay of communicators is that they are more likely to be promoted out of their job class into a higher job class. The CO line in this sample is the only one that has job positions. Production workers in the IO line in this sample all belong to the same job category.[15] When we regress years in their current position on Degree for the CO line, we find that higher communication lowers the probability of long tenure in the same job position. This could arise from a causal relationship (high communication produces promotion), or from heterogeneity (high communicators are more able workers).

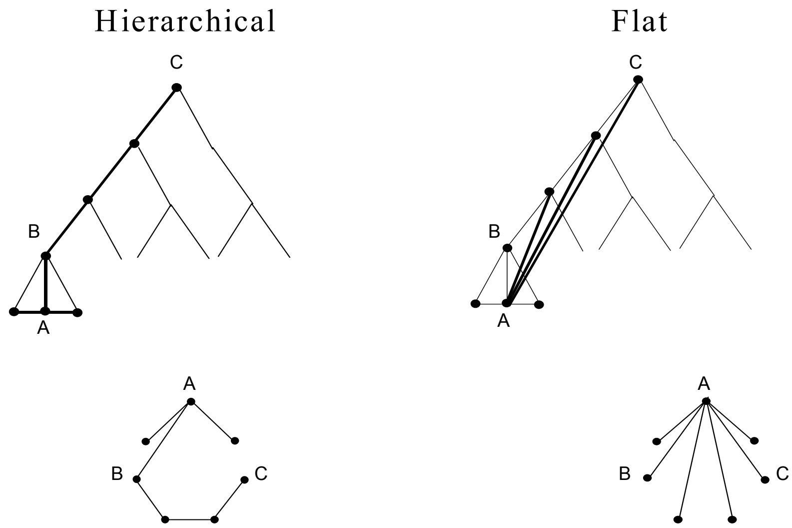
Though investments in connective capital do pay somewhat higher wages, it is unlikely that the average worker gains much in hourly base pay from his investment. His primary return therefore comes from the group-based incentive pay shared equally among all line workers as modeled in the theoretical framework in Section II. Figure 3 shows the distribution of connective capital Degree by wage quartile. Note that those individuals whose earnings place them only in the second wage quartile have a full range of Degree, and thus high communicators in this quartile are not well compensated in their base pay for their communications efforts.

The evidence in Table 4 suggests that communications explain a much greater percent of the relative pay differentials than do the standard human capital variables. Note however, that we cannot say whether high communicators earn higher levels of pay than low communicators across lines—these data cannot provide absolute wage differential comparisons.

4.5. Alternative Measures of Connective Capital

[14] Note that the team leaders on IO lines do the same jobs as the foremen on CO lines, so the relative pay comparisons, or operators to foremen or teams leaders, is a valid one.
[15] On IO lines, promotions occur through the pay-for-skills plan, in which pay rises by meeting skill standards, but we have no data on the skill grade of the employees.

Alternative Networks for Focal Actor A



Connective capital enhances the problem-solving skills of worker *i* by providing him with access to the information, expertise, and ideas of his co-workers . In measuring connective capital thus far, we focus on Degree Centrality, or the number of direct contacts that each person has to all other employees. However, workers can obtain information through "indirect ties." In Figure 3, we compare a "hierarchical" and a "flat" organization. This figure illustrates that person A in the hierarchical organization can obtain information from person C indirectly, since it can be passed to him through worker B. In the flat organization, person A talks directly to person C. Flat organizations may be more costly to run in terms of the time spent communicating. Thus, only firms that place a high value on direct communications should choose the flat organization (Bolton and Dewatripont, 1994).

Recognizing that information can be obtained both directly and indirectly, social network researchers have developed a series of network measures. We analyze a few that capture the potential value of indirect links (see Appendix B for equations defining these measures).

1. Degree Centrality (analyzed above) is the number of direct ties, so person A has 6 direct ties in the flat organization and 3 in the hierarchical or organization.
2. Information includes indirect ties in the network measure by adding the number of indirect ties, but weighting each tie by the inverse of the distance to that tie. For example, in the hierarchical figure, the links from A to C is weighted less than the link from A to B. Of course, person A still has a greater value of information in the flat organization, because for every direct tie, he links indirectly to everyone else with a shorter distance than does person A in the hierarchical.

3. Eigenvalue measures whether the person is centrally located in the information network, and is high when a person is located between two (or more) people who have a lot of access to "information." Though this is not well portrayed in Figure 3, one can imagine that person B (or one higher up) could have high Eigenvalue because he has direct access to information from the bottom of the hierarchy and is closer to the top.
4. Closeness measures the shortest distance to all possible actors in an organization—high closeness means easy direct access. Again, a mid-level manager such as B (or one higher up) could be expected to have high values of Closeness.

Analysis of these measures show that production workers undertake more problem-solving on IO lines by increasing the direct contact that they have with other employees—workers on IO lines have by far the greatest percentage point gains (relative to workers on CO lines) in direct ties than in the other network measures (see Table 5). The other measures all rise significantly, but the changes are less pronounced. Note also that the differences in communications are especially large for daily communications, suggesting that it is immediate problem-solving and information sharing that increases among operators on IO lines.

The communications gains for supervisors and managers on IO lines relative to CO encompass gains in more indirect as well as direct communications. The team leaders of these IO lines experience very large increases in daily communications relative to the foremen on CO lines, but team leaders also have a much richer and broader network. On IO lines, they have much greater access to all others (measured by the greater Closeness on IO lines) and are more likely to be located between individuals who have high information levels (as measured by the greater values of Eigenvalue on IO lines). In contrast, managers on IO lines have smaller changes in communications on IO lines. In particular, their daily communications are similar on IO and CO lines, though the weekly or monthly communications network is broader and richer for managers on IO lines.

Finally, holding constant the occupational differences in communications across IO and CO lines, there are individual-level differences in the investment in these networks that reinforce the results presented earlier (Table 6). All of these network measures decline with age. Older workers invest less, either because there are declining returns to investment or because they cannot change old patterns of behavior. In contrast, as tenure rises, workers have larger networks, and the networks expand the most for infrequent communications that occur on a weekly or monthly basis. The positive effect of education differs from that of tenure – more educated people are more likely to communicate on a daily basis.

Overall, the biggest gains in communications occur among production workers, team leaders, and staff members, as they have many more direct contacts with one another on a daily basis on IO lines than on CO lines. Thus, problem solving seems to improve from more frequent direct contact. On IO lines, indirect contacts change far less than direct contacts. While employees in all occupational groups see their direct contacts rise with IO practices, the staff and supervisors also change their information networks by having much greater access to everyone in the organization (measured by Closeness), and by being located between individuals who are valuable sources of information (measured by Eigenvalue).

V. Why Don't CO Lines Adopt New HRM Practices?

Two questions naturally arise from the empirical patterns documented in Section IV. If higher levels of worker interaction that support problem-solving activities are responsible for the higher levels of performance of IO lines, how do CO lines compete with IO lines that enjoy higher levels of worker productivity? Similarly, why don't CO lines adopt IO-style HRM practices to improve their productivity? In this section, we focus on the latter question about the transition costs of moving from a CO work environment to an IO work environment. Still, two observations concerning the first question are important. First, CO lines enjoy certain advantages not enjoyed by IO lines which can offset the IO lines' productivity advantage. Most important here are the smaller costs of capital in CO lines. These lines tend to be older. Second, CO lines do engage in some problem solving but in a different manner than the IO lines. In IO lines, operators and team leaders are actively engaged in problem-solving along with managers and staff. In CO lines, some problem-solving exists, but it is undertaken by largely by managers (including engineers) and foremen, with some assistance from a small number of operators. Figure 4, for example, shows that a small number of operators on CO lines have high values of the Degree statistic.

Even if CO lines do tend to have certain advantages in their cost structure, why don't these lines boost their productivity through the adoption of new HRM practices and higher levels of employee participation and problem-solving? The most striking evidence on this point is in the difference in the dates that IO and CO lines began operations. IO lines all began operations since 1983. However, this does not mean that the capital stock is of relatively recent vintage in IO lines. More specifically, IO lines are either lines at "greenfield" sites or "reconstituted" lines. The former group of lines are those with brand new capital that were built on sites that previously had no manufacturing facilities, typically far from urban settings. The latter group of lines consists of older lines that have been shut down for some time, but were bought and reopened by new owners. What these two types of lines have in common, whether they have new or old capital, is that the workforce is new. Managers do not have to make changes from an existing set of work practices, and workers do not have an established set of work relations. That is, since workers are being newly hired, there is no pre-existing social network structure at these lines. Managers are designing policies that will define the initial social structure.

In contrast, CO lines in this sample (and in our earlier study's sample of 36 finishing lines) began operations prior to the mid-1960's. At the time of this study, the lines have been in continuous operation for three or more decades. The process of adopting IO-oriented HRM systems in these older, continuously operating lines is therefore more problematic. Traditional work practices put in place many years ago promoted a very different "work culture" and a very different set of social relationships among workers from the kind found in IO lines. The costs of changing from a pre-existing system of traditional HRM practices to an innovative HRM system involve more than just the direct costs of the HRM policies and shed light on the source of other transition costs. For older, continuously operating lines with traditional work practices to adopt innovative HRM practices, the entire pre-existing social structure of work relationships must be undone. This is a transition cost that no IO finishing line in the United States had to overcome.[16]

While the research reported here makes it clear that workers in CO lines would need to forge many new inter-worker relationships, our field visits also revealed many impediments that would make it costly to create a new system of worker relations. First, workers do not believe there are large incentives for working more cooperatively with others. We observed that many workers were apathetic about doing more than they were already doing. The impediment here appears to be different than implementing some gainsharing or some new version of a group incentive pay plan. Even if rewards from productivity gains are shared in a new way with workers under an agreed-upon pay plan, a large proportion of workers at the CO lines would need to be convinced that a more cooperative and interactive work environment would lead to improved performance. After all, workers in CO lines would argue, our line already "works."

Second, CO workers would need to devote a significant amount of time to acquire a broader range of technical knowledge and skills to make new worker ties valuable conduits of information. The scope of knowledge that workers have across jobs is decidedly greater in the IO lines. For example, we often asked workers to tell us which other workers could step in on their jobs and perform the job just as well. Workers at IO lines cited long lists of capable replacements, while at the CO line the list of replacements included few, if any, other equally capable replacements. This pattern in the CO line would create a dilemma in how one would go about a retraining program, since some workers would not be easily replaced were they to participate in some long-term skill-broadening training program. More specifically, workers on CO lines appear to be specialists at certain jobs, so finding capable replacements during extensive cross-training programs would not be an easy task.

Third, the training required to forge new relationships at the CO line would also involve training in communication, problem-solving, and team-work skills. Most CO production workers, as well as the staff and some managers, have not worked in environments where interpersonal communication skills and problem-solving skills are

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[16] For further evidence on the relationship between age of continuously operating lines and the adoption of innovative HRM practices, see Ichniowski and Shaw (1995).

part of how workers interact to get their jobs done. The IO plants recognize the importance of these skills and include training sessions for these skills. This training includes skills on how to run a meeting, how to participate in a meeting, how to participate in an ad-hoc problem-solving activity, how to document problems, and how to write a memo. These skills are also rewarded as part of the pay-for-knowledge system. At IO line 1, the operators pointed directly to the section of the employee manual that described all of the communication skills that are required for their jobs. The crew members, crew leader, and managers sign-off on each crew member's skills in these areas as part of their employment records.

The impediments listed above could be addressed in part by new HRM policies. Improved group incentives could help, even though employees would still need to be convinced that a new approach for organizing work could produce better results. Training in a broader set of skills and jobs would make information flows across workers more valuable, even though these training programs would have to address how to remove critical workers from the lines for extended periods. Still, the HRM policies appear to be only a part of the solution to these impediments.

At the same time, we also see evidence from our field visits of impediments to forging new worker relationships that cannot simply be addressed by introducing a new "management policy." First and foremost is the issue of low levels of trust among many workers, especially managers and line employees. Many CO line employees, like employees at many large integrated steel mills, are long tenured employees. Their experience dates back to periods of mass layoffs in the 1980's. Their experience includes many rounds of bitter labor negotiations and histories of adversarial shop-floor relations. For example, both union and management workers commented that management was still very nervous about giving power and decision-making authority to the production workers. Even a seemingly simple development like the institution of a pre-shift meeting raises management concerns that this greater interaction among union members could serve to strengthen the union. While it may be an obvious point, workers do not interact much with other employees whom they do not trust.

Finally, the smaller number of "central" workers, or those with especially dense communication networks, at the CO line implies a much more concentrated group of influential workers at the CO lines (as shown in the distribution of Degree in Figure 4). These workers are clearly high-status individuals at the CO line. While differences in the influence of workers did clearly exist at the IO lines, we do not observe the same kind of concentration of high status individuals at these lines. The critical employees at the CO line have invested many years in developing their particular positions at their line. A change to a more participatory and interactive work environment could well diminish the relative influence of these workers and change the nature of their roles at the workplace in ways that these workers would not favor.

One way to summarize the impediments to the development of a more extensive set of work relationships at the CO line is to consider the responses of CO production workers to the question of why they do not participate in their mill's teamwork initiatives. Like many traditional work organizations, these lines are attempting to introduce elements of a "high performance" work system, and central to those efforts is the introduction of off-line problem-solving teams. Yet, relatively few employees at the CO line are involved in these teams. CO production workers give a number of reasons for a lack of participation in the teams—reasons that are consistent with the impediments to forging new ties that we list in this section. Workers say they doubt they will see any extra pay that from participating more. Workers cannot find capable relief workers for their position. Workers feel that the teams are not well run. From their perspective, teams accomplish very little, and the workers' opinions do not matter to managers. Finally, workers said that they do not trust managers or the teamwork initiative that managers instituted.

For lines starting at greenfield sites, or for "reconstituted" lines that are reopened by new managers, the costs enumerated above do not exist. Managers at these lines can implement innovative HRM policies without having to rearrange a pre-existing social structure of long-standing employee work relationships. Greenfield and reconstituted lines can establish new norms about participation and a new work culture when they begin operating with a new workforce. Changing to a new set of norms and a new culture after years of bitter labor-management relations, large-scale layoffs, and a control-oriented management style is a very costly process. We argue that these transition costs are important reasons for the limited adoption of IO-style work policies in older, continuously operating finishing lines.

VI. Conclusion

This study provides evidence that firms with innovative HRM practices are investing in the "connective capital" of their workforces. Workplace communications among employees, especially among production and maintenance workers, are much more extensive under innovative and participatory HRM practices than under traditional work practices. In innovative lines, all workers communicate more extensively to solve operating problems on the lines. These differences in the behavior of workers across workplaces with similar technologies but different HRM practices help account for the finding in the literature that manufacturing firms with systems of innovative HRM practices achieve higher levels of productivity than do lines with more traditional work arrangements.

At the same time, these investments in connective capital can be costly – involving higher training, screening, and information sharing costs, and potentially higher wages. An existing business with traditional HRM practices that attempts to promote more employee participation by adopting the innovative HRM practices also faces transition costs beyond the direct costs of the participatory HRM practices themselves. The business also faces the costs of overhauling an entire set of social relations and interactions among employees, and the costs of undoing an existing set of work norms before a new participatory work culture can be developed.

References

Aoki, Masahiko (1986), "Horizontal vs. Vertical Information Structure of the Firm," *American Economic Review*, vol. 76, (December), pp. 971-983.

Appelbaum, Eileen and Peter Berg (1998), "Hierarchical Organization and Horizontal Coordination: Evidence from a Worker Survey," working paper.

Black, Sandra and Lynch, Lisa (1997) "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity," working paper.

Berg, Peter, Eileen Appelbaum, Thomas Bailey, and Arne L. Kalleberg (1997) "The Performance Effects of Modular Production in the Apparel Industry," *Industrial Relations*, vol. 35 (July), pp. 356-373.

Bolton, Patrick and Mathias Dewatripont. (1994) "The Firm as a Communication Network," *Quarterly Journal of Economics*, vol 109, no. 4, (November) pp. 809-839.

Boning, W. Brent, Casey Ichniowski, and Kathryn Shaw (2000) "Making Production Incentives Effective: Opportunity Counts" working paper.

Borgatti, Everett, and Freeman (1996), "UCINET IV Version 1.64 Reference Manual," Analytic Technologies Natick, MA.

Dunlop, John T., and David Weil (1997) Diffusion and Performance of Modular Production in the U.S. Apparel Industry," *Industrial Relations*, vol. 35 (July), pp. 334-355.

Geanakoplos, J. and Paul Milgrom, (1991) "A Theory of Hierarchies Based on Limited Managerial Attention," *Journal of the Japanese and International Economies*, pp. 205-225.

Glaeser, Edward L., David Laibson, and Bruce Sacerdote. (2000) "The Economic Approach to Social Capital," NBER Working Paper no. 7728, (June).

Huselid, Mark (1995) "The Impact of Human Resource Management Practices on Turnover, Productivity, and Corporate Financial Performance," *Academy of Management Journal*, vol. 38, pp. 635-672.

Ichniowski, Casey and Kathryn Shaw (1995) "Old Dogs and New Tricks: Determinants of the Adoption of Productivity-Enhancing Work Practices," *Brookings Papers on Economic Activity: Microeconomics*, pp. 1-65.

Ichniowski, Casey, Kathryn Shaw, and Giovanna Prennushi (1997) "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines," *American Economic Review*, vol. 87, pp. 291-313.

Ichniowski, Casey, Thomas A. Kochan, David Levine, Craig Olson, and George Strauss (1997) “What Works at Work: Overview and Assessment,” *Industrial Relations*, vol. 35 (July), pp. 299-333.

Ichniowski, Casey and Kathryn Shaw (1999) “The Effects of Human Resource Management Systems on Economic Performance: An International Comparison of U.S. and Japanese Plants,” *Management Science*.

Ichniowski, Casey and Kathryn Shaw (2002) “Beyond Incentive Pay: Insiders’ Estimates of the Economic Value of Complementary HRM Practices” (manuscript).

Jensen, Michael and William H. Mechling (1992) “Specific and General Knowledge, and Organizational Structure,” in *Contract Economics*, eds. Lars Werin and Hans Wijkander (Blackwell, Oxford) pp. 251-274.

Kandel, Eugene and Edward Lazear (1992) "Peer Pressure and Partnerships" Journal of Political Economy, vol. 100, pp. 801-817.

Keren, M. and D. Levhari, (1979) “The Optimum Span of Control in a Pure Hierarchy,” *Management Science*, vol 40, pp. 1162-1172.

Knack, S., and P. Keefer (1997) "Does Social Capital Have an Economic Payoff? A Cross-Country Investigation," *Quarterly Journal of Economics*, vol. 112, pp. 1251-1288.

Leana, Carrie and Harry Van Buren, III, (1999) "Organizational Social Capital and Employment Practices", *Academy of Management Review*, vol. 34, no. 3, pp. 538-555.

MacDuffie, John Paul (1995) “Human Resource Bundles and Manufacturing Performance: Organizational Logic and Flexible Production Systems in the World Auto Industry,” *Industrial and Labor Relations Review*, vol. 48, pp. 197-221.

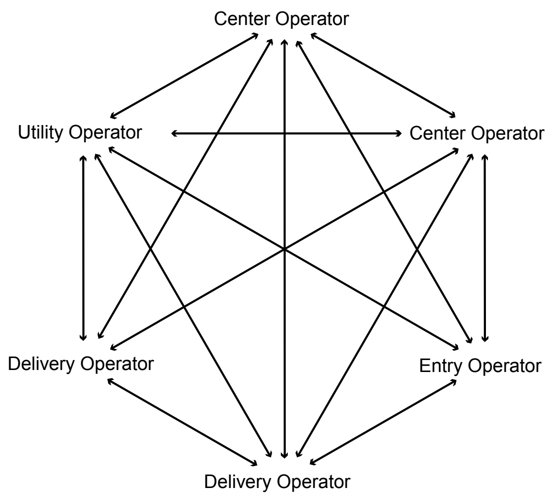
Manski, Charles (2000) “Economic Analysis of Social Interactions,” NBER Working Paper no. 7580.

Marshall, Alfred (1965) *Principles of Economics* (Macmillan, London).

Milgrom, Paul and John Roberts (1990) “The Economics of Modern Manufacturing,” *American Economic Review*, vol. 80, no. 3, pp. 511-28.

Nahapiet, Janine and Sumantra Ghoshal (1998) “Social Capital, Intellectual Capital, and the Organizational Advantage,” *Academy of Management Review*, vol. 23, no. 2, pp. 242-266.

Figure 1a - intra-crew Communication Interactions for IO Line 1



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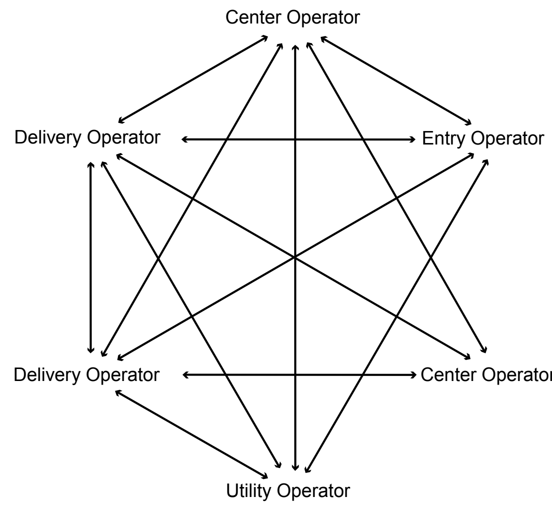

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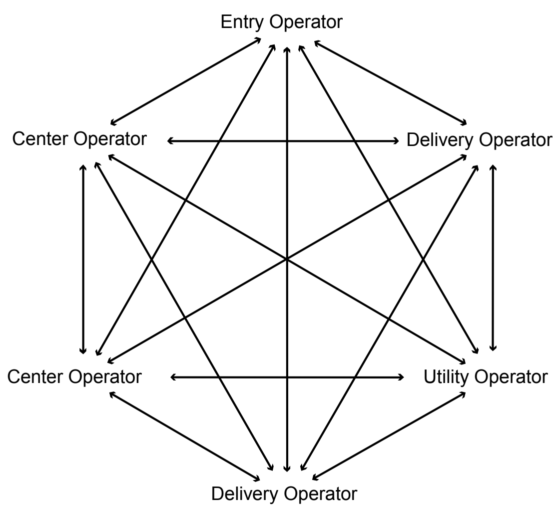

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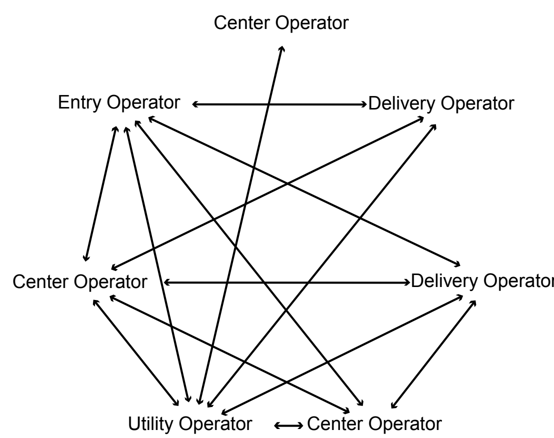
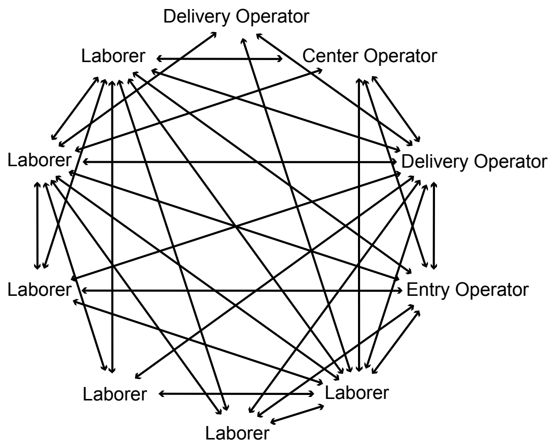


Crew D

Figure 1b - intra-crew Communication Interactions for IO Line 2



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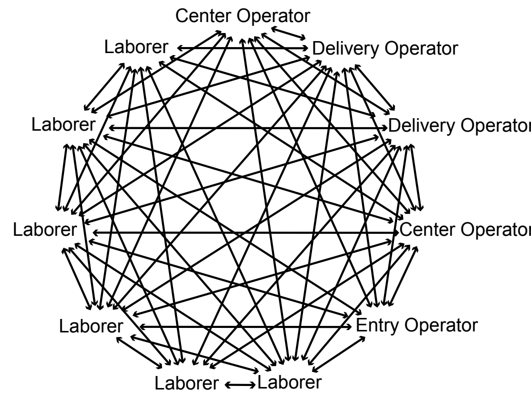

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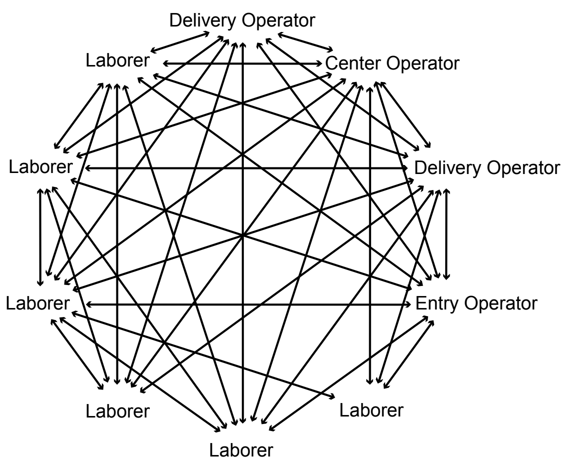

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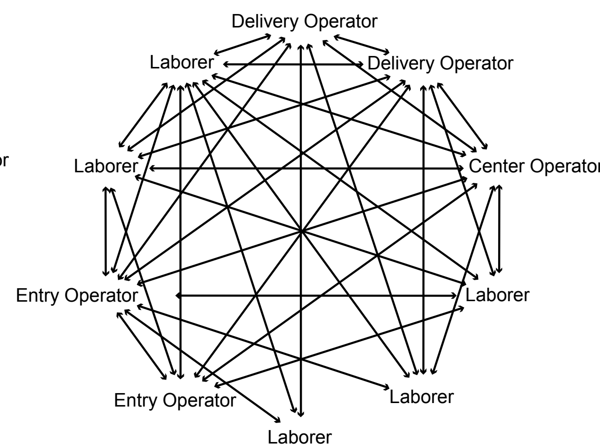


Crew D

Figure 1c - intra-crew Communication Interactions for CO Line 1

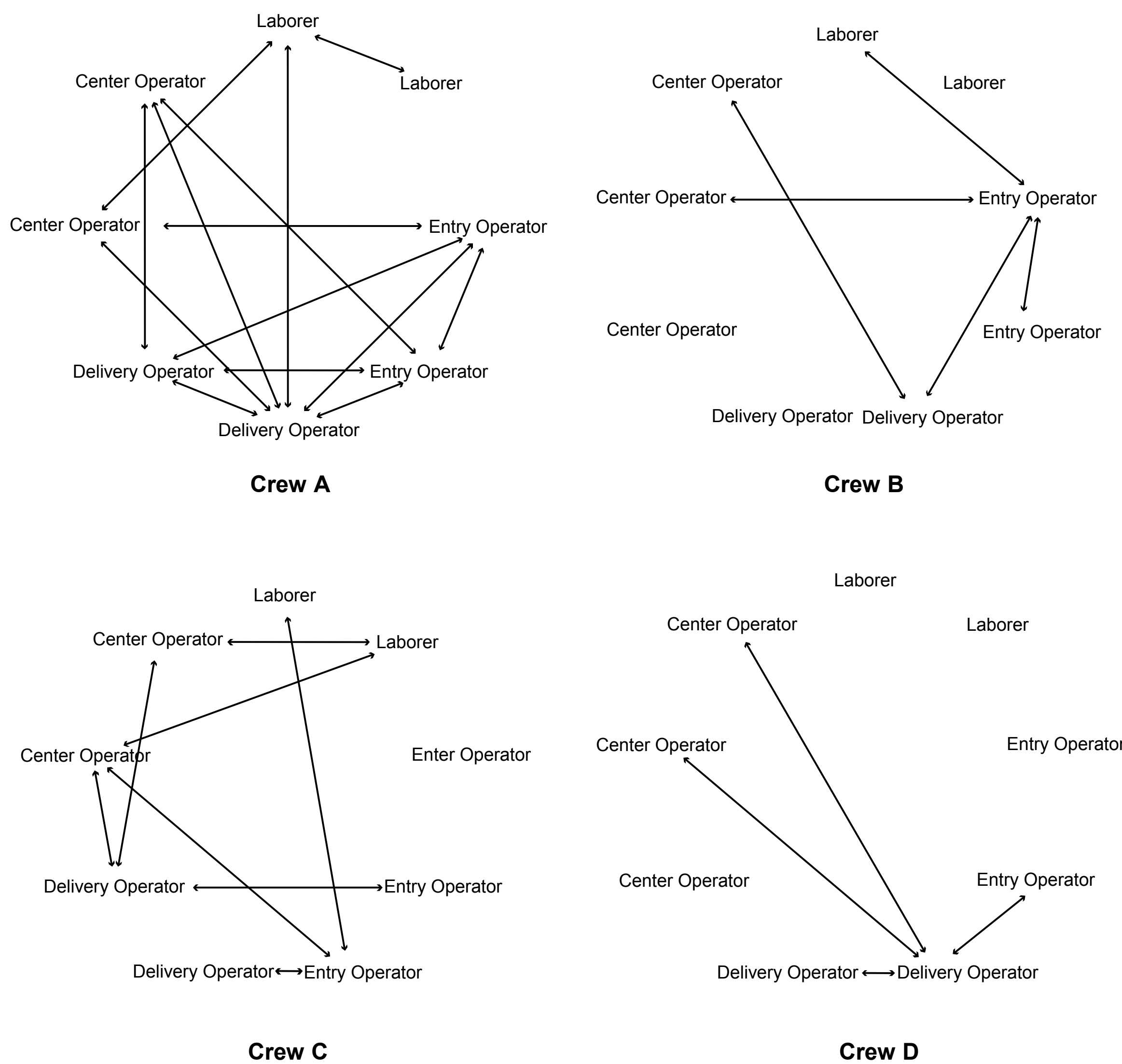


Figure 1d - intra-crew Communication Interactions for CO Line 2

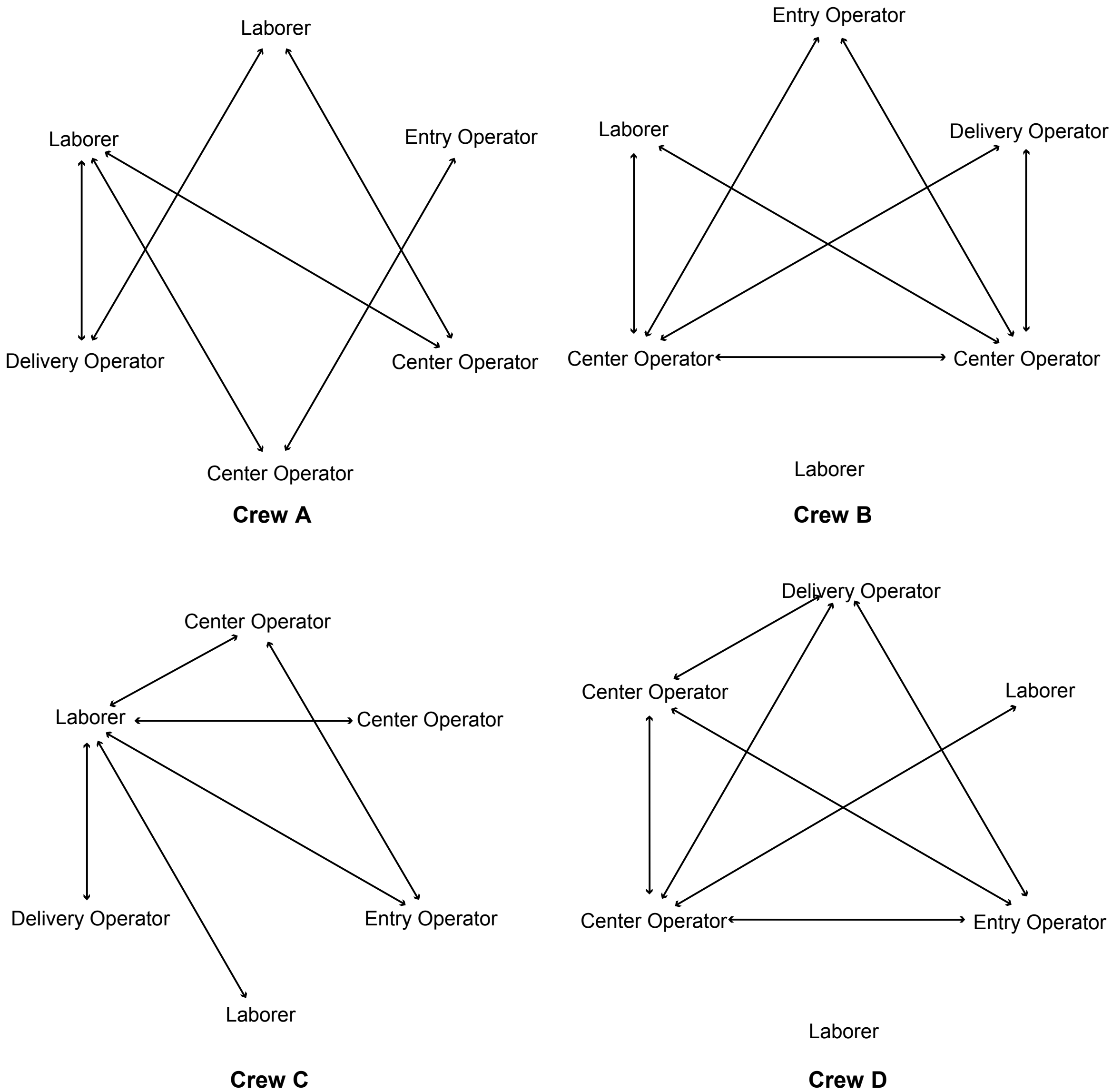


Figure 2a – Inter-group Communication Interactions for IO Line 1

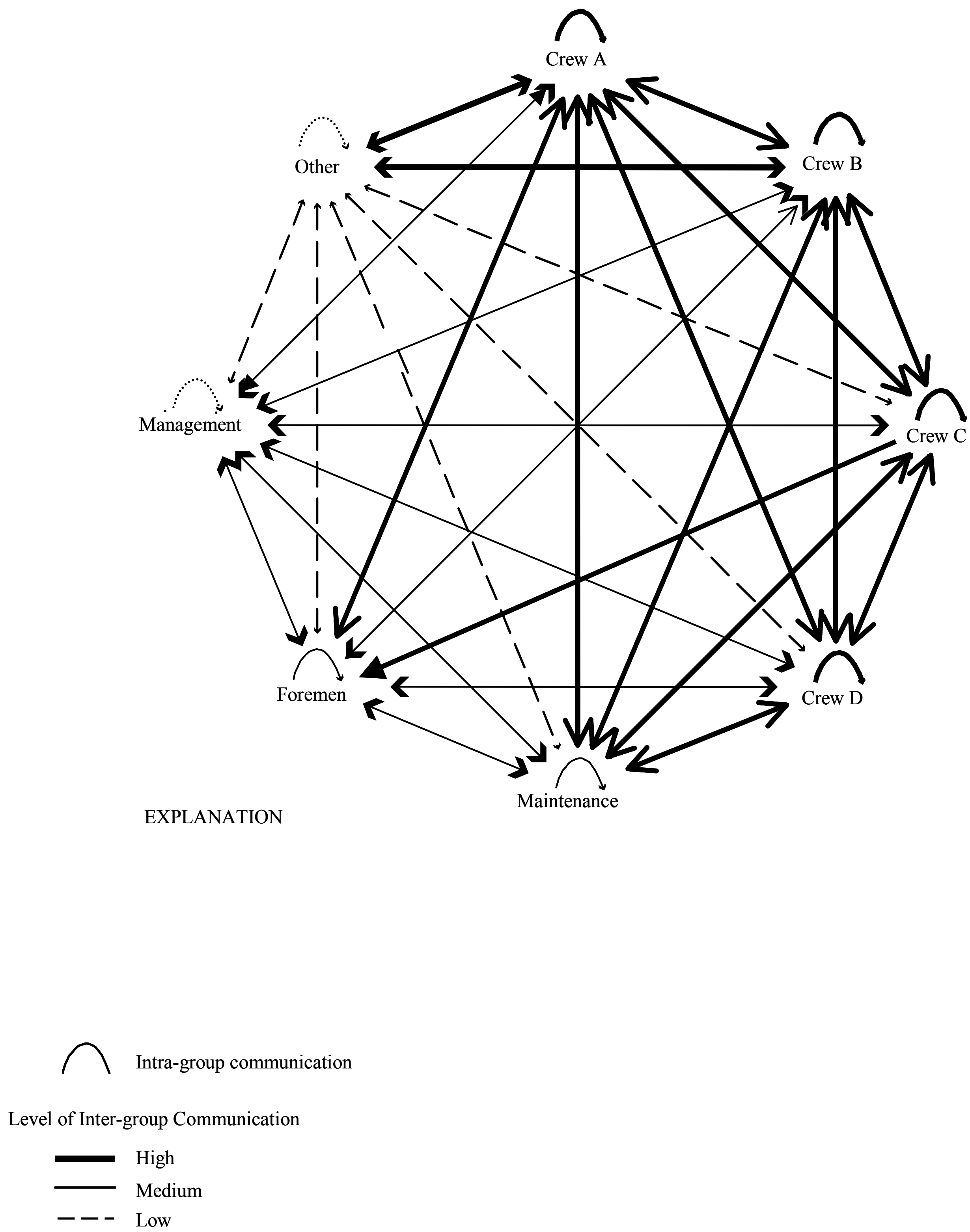


Figure 2b – Inter-group Communication Interactions for IO Line 2

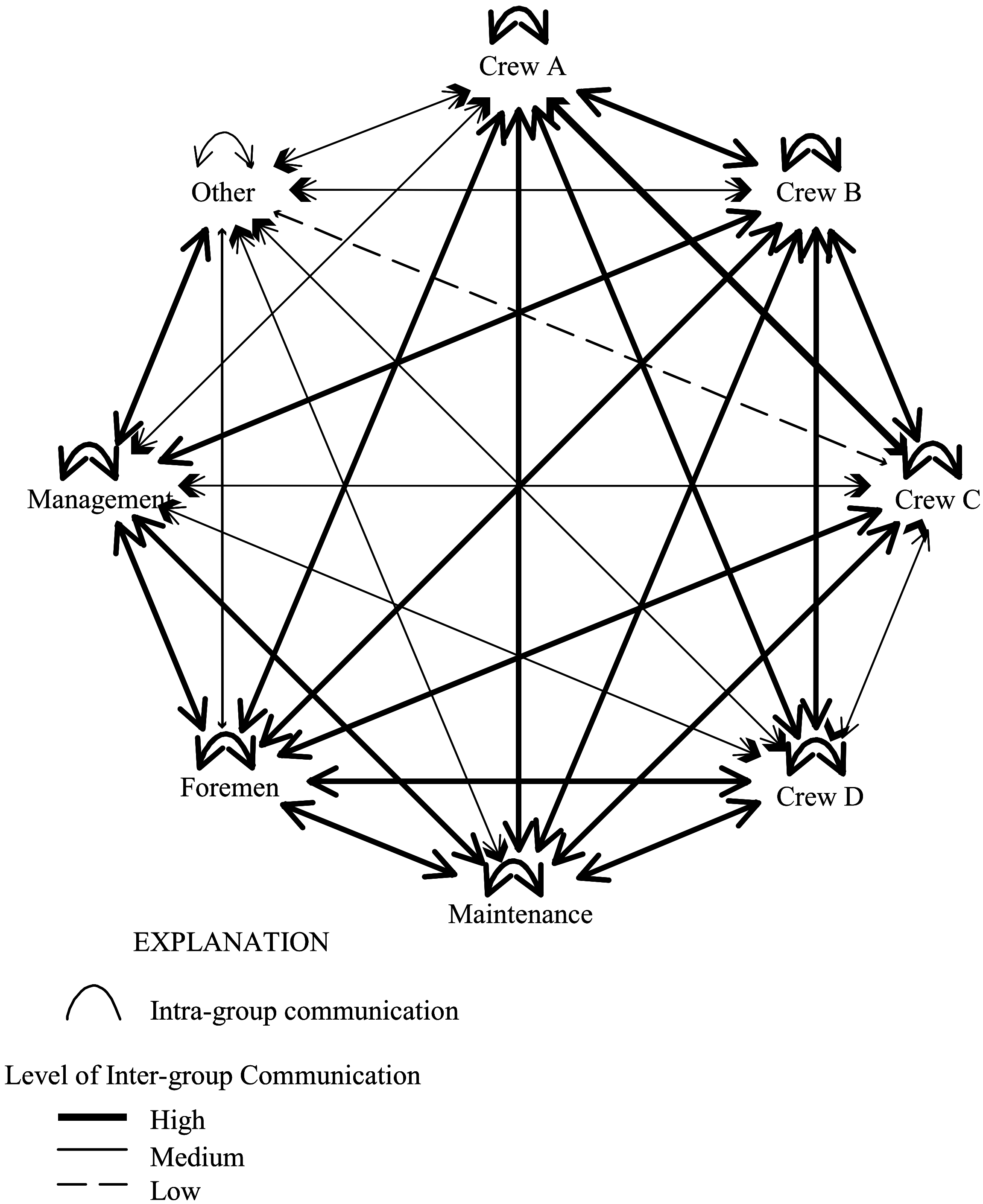
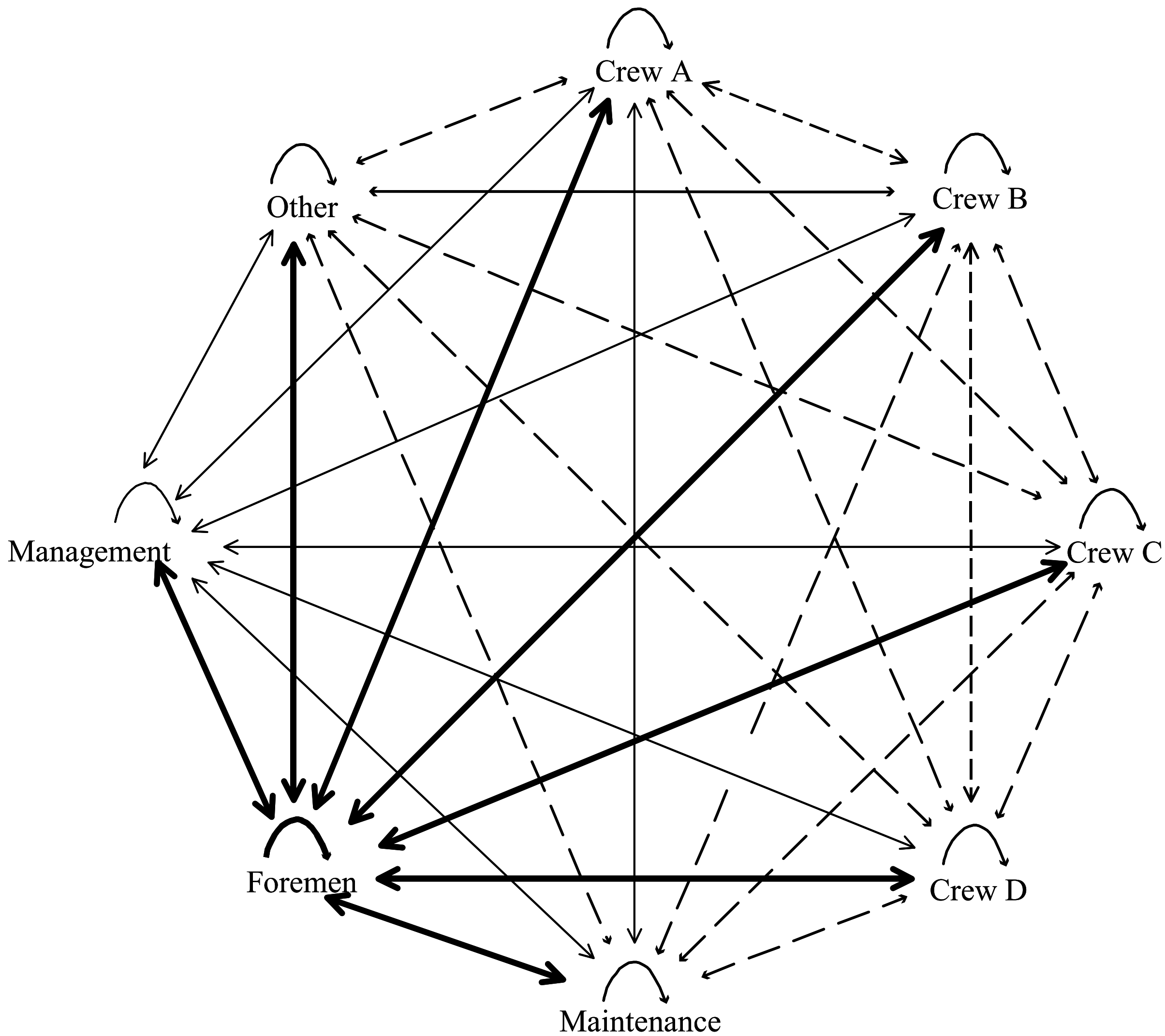


Figure 2c - Inter-group Communication Interactions for CO Line 1



EXPLANATION

Intra-group communication

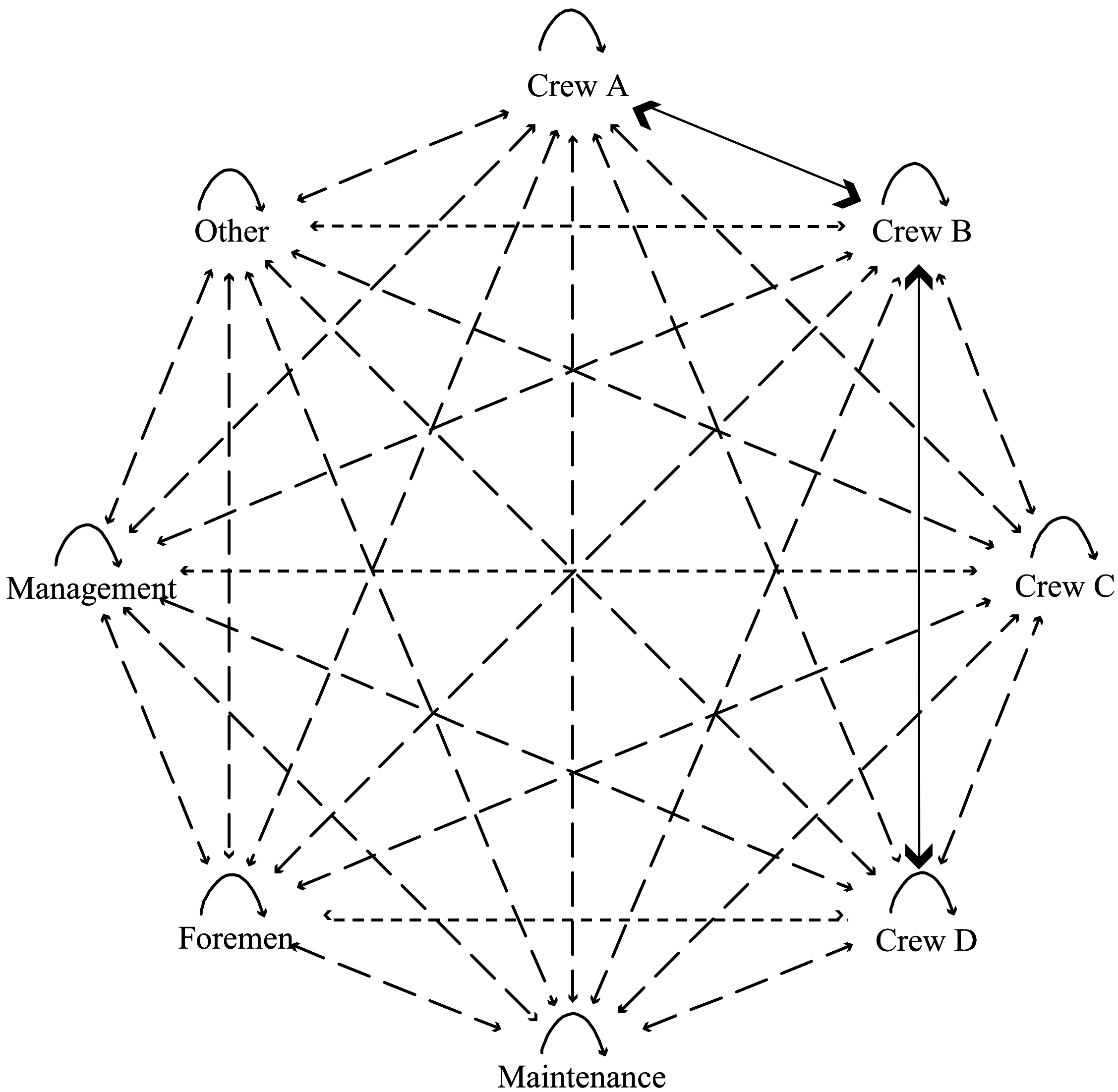
Level of Inter-group Communication

High

Medium

Low

Figure 2d – Inter-group Communication Interactions for CO Line 2



EXPLANATION

Intra-group communication

Level of Inter-group Communication

High

Medium

Low

Table 1

Measures of Aggregate Human Capital Based on Equation (3)

TYPE		Aggregate Human Capital				
		HUMAN CAPITAL (hc)		CONNECTIVE CAPITAL[a]		
		Education	*Tenure*	**Education**	**Tenure**	**Tie Density**
Control-Oriented	Average	13.26 %hs=56 %coll=17	13.67 (7.4)	340.9 (152.3)	298.8 (349.5)	.117 (.161)
Involvement-Oriented	Average	13.22 %hs[b]=59 %coll[c]=20	11.86 (5.7)	664.7 (133.3)	535.4 (228.3)	.387 (.275)

a-standard deviations in parantheses
b - %hs is the percent of workers with a high school degree or less;
c - %coll is the percent of workers with a college degree or more.

Table 2

Tobit Results for Degree Centrality

DEPENDENT VARIABLE	DEGREE CENTRALITY			
	All Ties (1)	***All Ties* (2)**	**Strong Ties (3)**	**Weak Ties (4)**
Production Workers	.136 (17.08)	.135 (15.43)	-.025 (-2.19)	.044 (3.71)
Managers	.142 (15.48)	.155 (13.39)	-.021 (-1.27)	.052 (3.22)
Non-Production Staff	.228 (12.98)	.116 (14.67)	.053 (-4.98)	.034 (3.25)
Foremen/Team Leaders	.119 (16.11)	.126 (3.85)	-.067 (-1.37)	.040 (0.84)
Involvement-oriented HRM Practices (IO)	.192 (35.78)			
Production Workers*IO		.192 (25.59)	.122 (11.21)	.164 (14.66)
Managers*IO		.166 (12.17)	.025 (1.25)	.212 (10.55)
Non-production Staff*IO		.197 (20.86)	.159 (11.42)	.169 (12.12)
Foremen/Team Leader*IO		.333 (8.80)	.276 (4.92)	.277 (4.99)
Log likelihood	761.7	770.79	367.29	577.74
N	5688	5688	1896	1897

Tobit models have mass points at zero and one. Also included are controls for type of communication topic.

Table 3

Tobit Results for Degree Centrality with Human Capital Variables

DEPENDENT VARIABLE	DEGREE CENTRALITY		
	All Ties (1)	**Strong Ties (2)**	**Weak Ties (3)**
Production Workers*IO	.219 (16.79)	.118 (6.17)	.198 (10.09)
Managers*IO	.307 (13.58)	.114 (3.36)	.332 (9.85)
Non-production Staff*IO	.294 (19.98)	.229 (10.32)	.263 (12.07)
Foremen/Team Leader*IO	.325 (7.54)	.263 (4.06)	.276 (4.37)
Age – Operators	.0000 (0.07)	-.0014 (-1.58)	.0007 (0.79)
Non-operators	-.0046 (-6.21)	-.0051 (-4.66)	-.0038 (-3.57)
Tenure – Operators	.0016 (1.82)	.0020 (1.55)	.0007 (0.50)
Non-operators	.0031 (3.21)	-.0032 (-2.05)	.0072 (4.87)
Education – Operators	.1214 (2.00)	.255 (2.84)	-.031 (-0.34)
Non-operators	.225 (4.80)	.199 (2.85)	.259 (3.68)
$(\text{Education})^2$ – Operators	-.004 (-1.92)	-.0089 (-2.82)	.001 (0.40)
Non-operators	-.0078 (-4.77)	-.0070 (-2.89)	-.009 (-3.61)
Log-likelihood	405.2	169.92	286.71
N	2666	888	893

Tobit models have mass points at zero and one. Also included are controls for type of communication topic.

Table 4

Wage Ratio and Promotion Regressions

	Wage Ratio				Job Tenure
	(1)	(2)	(3)	(4)	(5)
IO		.243 (18.61)		.184 (8.37)	
Degree			.414 (13.68)	.139 (3.49)	
Education – Operators	-.034 (-3.08)	-.007 (-1.28)	-.011 (-1.66)	-.006 (-1.20)	-.097 (-0.30)
Non-Operators	-.006 (-0.42)	.0000 (-0.09)	.007 (0.92)	.016 (2.69)	-.91 (-1.93)
Tenure – Operators	-.004 (-1.62)	.0000 (-0.09)	.0005 (0.36)	.004 (0.39)	.026 (0.39)
Non-Operators	-.008 (-1.72)	.002 (0.73)	.003 (1.11)	.003 (1.38)	.47 (2.73)
Operator	1.15 (7.55)	.624 (8.38)	.644 (6.84)	.588 (8.34)	3.42 (0.70
Non-Operator	.77 (4.17)	.215 (2.41)	.318 (2.87)	.205 (2.45)	15.76 (2.169
N Degree – Operator					-2.96 (-0.52)
Non-Operator					-18.58) (-2.90)
Log Likelihood	59.78	130.0	109.9	135.7	.80
N	88	88	88	88	37

Note: The Wage Ratio is the individual's wage divided by the wage of the highest paid foreman or team leader for his line. The model is estimated as Tobit with [0,1] mass points. The Job Tenure is the years in the current job position.

Table 5
Tobit Results for Alternative Network Measures

	N Degree	Information	Closeness	N Eigen	N Degree	Information	Closeness	N Eigen
	All Ties				Strong Ties			
Operator	.157 (19.43)	5.20 (35.86)	44.52 (49.22)	.091 (28.39)	.013 (1.21)	.783 (5.33)	8.49 (7.87)	.061 (8.67)
Manager	.177 (16.63)	4.90 (24.32)	44.96 (35.71)	.106 (21.31)	.018 (1.12)	.644 (2.96)	7.57 (4.74)	.070 (6.62)
Staff	.138 (17.32)	4.44 (31.41)	42.99 (48.69)	.073 (20.86)	-.015 (-1.39)	.520 (3.65)	.456 (4.26)	.010 (1.34)
Supervisor	.148 (4.56)	4.80 (8.41)	44.21 (12.41)	.114 (8.11)	-.028 (-0.59)	.219 (0.34)	1.88 (0.40)	.057 (1.81)
IO* Operator	.192 (25.09)	2.55 (19.01)	4.91 (5.88)	.044 (13.35)	.122 (11.21)	.971 (6.36)	4.45 (3.98)	.048 (6.61)
IO* Main	.166 (12.17)	2.55 (10.52)	6.09 (4.03)	.010 (1.70)	.025 (1.25)	.278 (1.00)	-.21 (-0.10)	-.037 (-2.77)
IO* Staff	.197 (20.86)	1.23 (7.40)	-1.91 (-1.83)	.056 (13.64)	.159 (11.42)	.617 (3.23)	4.46 (3.19)	.079 (8.52)
IO* Supervisor	.333 (8.80)	284 (4.25)	6.25 (1.49)	.074 (4.49)	.277 (4.90)	2.63 (3.44)	13.71 (2.45)	.121 (3.29)
Log likelihood or R^2	770.79	.533	.53	4940.0	367.3	.20	.23	958.3
	5688	5688	5688	5688	1896	1896	1896	1896

Table 6

Tobit Results for Network Variables with Human Capital

	N Degree	Information	Closeness	N Eigen	N Degree	Information	Closeness	N Eigen
	All Ties				Strong Ties			
IO* Operator	.229 (18.60)	3.47 (13.86)	6.69 (5.17)	.032 (6.03)	.111 (6.10)	.851 (3.24)	2.31 (1.24)	.010 (0.82)
IO* Manager	.291 (13.83)	3.37 (7.91)	11.92 (5.42)	.052 (5.71)	.132 (4.18)	.738 (1.65)	1.79 (0.56)	.043 (1.96)
IO* Staff	.302 (20.98)	1.73 (5.96)	-.076 (-0.05)	.097 (15.61)	.245 (11.13)	.595 (4.95)	7.97 (3.67)	.126 (8.31)
IO* Supervisor	.304 (7.26)	2.87 (3.39)	3.47 (0.80)	.072 (3.98)	.289 (4.52)	3.33 (3.76)	15.06 (2.38)	.153 (3.53)
Age	-.0019 (-3.93)	-.019 (-1.96)	-.179 (-3.52)	-.0006 (-2.91)	-.003 (-4.06)	-.028 (-2.72)	-.191 (-2.60)	-.0002 (-0.51)
Tenure	.0025 (3.88)	.020 (1.51)	.164 (2.44)	.0003 (1.03)	-.0004 (-0.40)	.0017 (0.12)	-.051 (-0.52)	-.0014 (-2.10)
Education	.169 (4.59)	-.200 (-0.27)	1.84 (0.48)	.077 (4.84)	.197 (3.60)	1.628 (2.09)	10.28 (1.85)	.110 (2.91)
Education ^{2}	-.0058 (-4.51)	.009 (0.34)	-.056 (-0.41)	-.0027 (-4.82)	-.0070 (-3.62)	-.057 (-2.08)	-.370 (-1.89)	-.0038 (-2.88)
Log likelihood or R^2	386.3	.52	.66	2350.5	158.0	.20	.24	397.8
	2666	2666	2666	2666	888	888	888	888

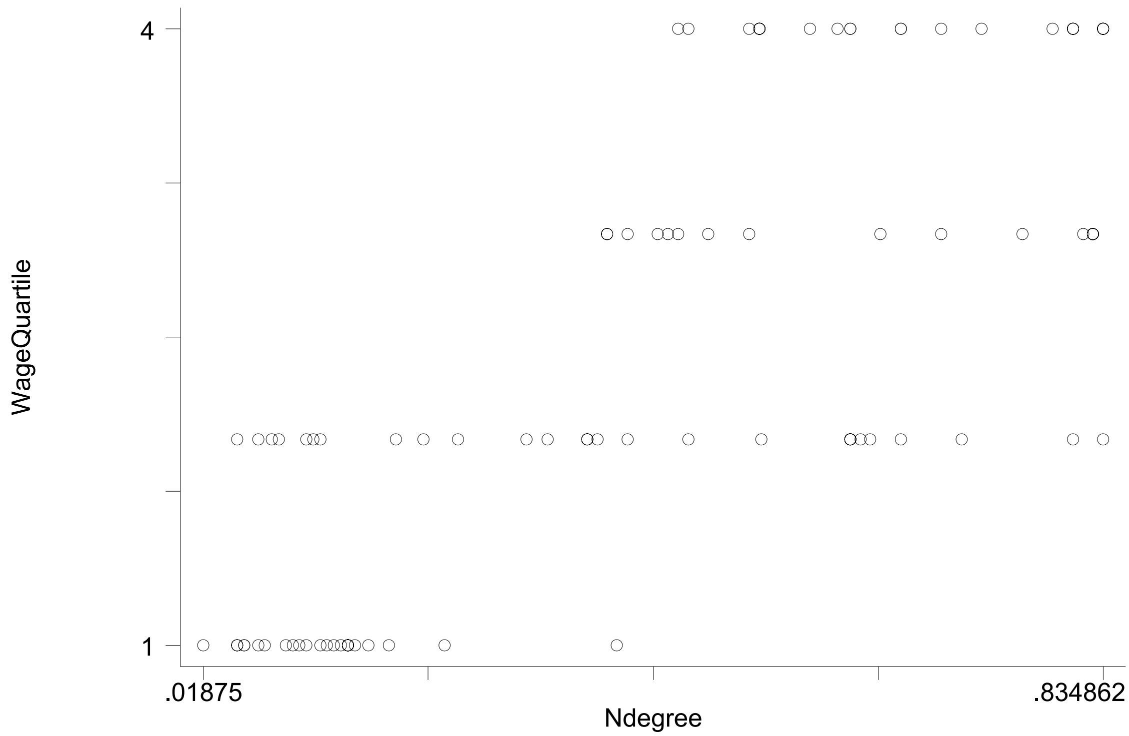
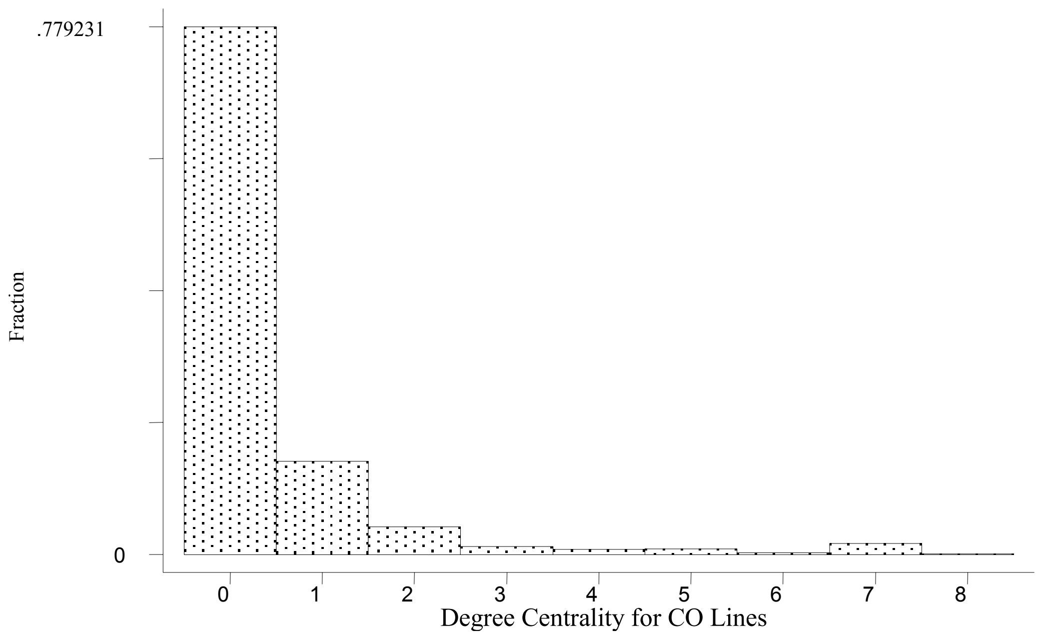
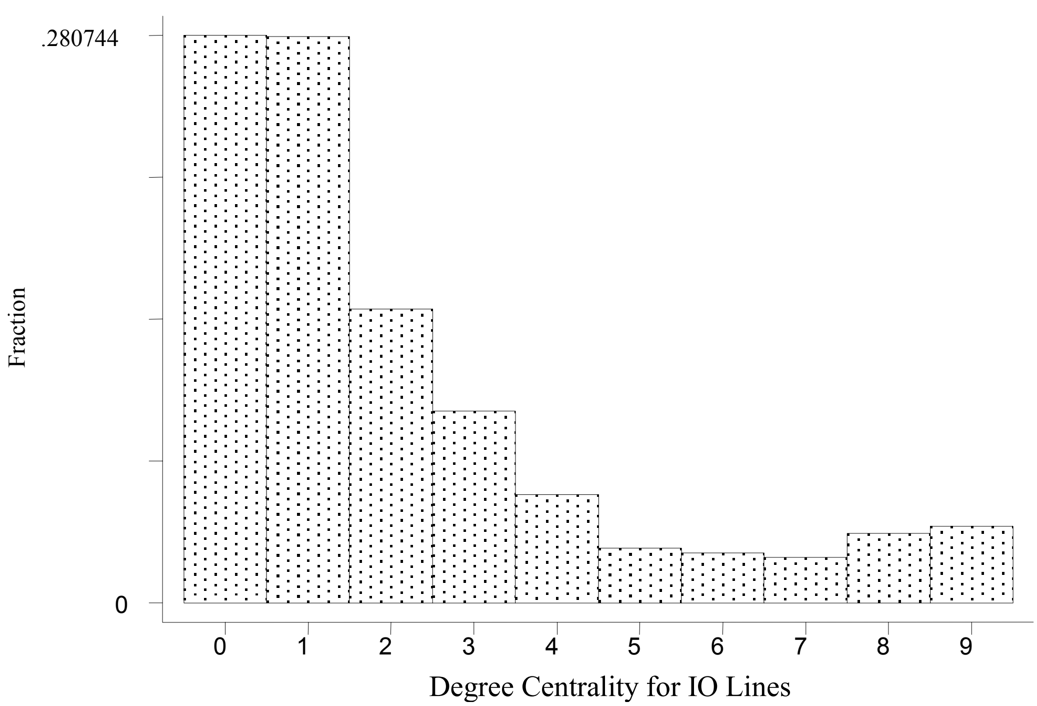


Figure 3: Degree Centrality Distribution by Wage Quartile

Figure 4

Distribution of Degree Centrality





Appendix A - Summary of Communication Survey Questions

Here is a summary of the questions that are included in the communication survey. The survey is relatively easy to fill out and takes between 10-15 minutes. The survey is organized with one question per page. The rest of the page contains the names of all of the employees. Beside each employee name are three check boxes indicating the frequency of communication. Each respondent will be asked to read each question and place a check mark by the name of each employee's name that meet the question's criteria.

For example, below is a brief illustration of one page from the survey.

With whom do you typically communicate?

Please check as many names as may be appropriate.

	Daily	Weekly	Monthly or less		Daily	Weekly	Monthly or less
Adams, Fred	[ ]	[ ]	[ ]	Hurley, Stanley	[ ]	[ ]	[ ]
Christopheson, Bill	[ ]	[ ]	[ ]	Marshall, Jim	[ ]	[ ]	[ ]
Haynes, Lester	[ ]	[ ]	[ ]	Smith, Don	[ ]	[ ]	[ ]
Lieman, Mary	[ ]	[ ]	[ ]	Norville, David Jr.	[ ]	[ ]	[ ]
Jordan, Barb	[ ]	[ ]	[ ]	Ostertag, John	[ ]	[ ]	[ ]
Childs, Tim	[ ]	[ ]	[ ]	Patton, Mike	[ ]	[ ]	[ ]

The survey questions include:

1. With whom do you typically communicate?
2. Who do you communicate with about operational issues?
3. Who do you communicate with about safety issues?
4. Who do you communicate with about quality issues?
5. Who do you communicate with about maintenance issues?
6. Who do you communicate with about customer issues?
7. Who do you communicate with about supplier issues?
8. Who do you communicate with about job related routines that you have developed?
9. Who do you communicate with about the performance of the company issues?
10. Who are you dependent on for critical information in doing your job?
11. Who is dependent on you for critical information in doing their job?
12. How much training would you need to fill-in for the following employees
13. With whom would you feel comfortable filling-in for you?

All of the surveys will be handed out by the research team along with an envelope. The respondents will be instructed to return the survey in this envelope and seal it to members of the research team. This will help to protect the confidentiality of the responses.