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Old Dogs and New Tricks: Determinants of the Adoption of Productivity-Enhancing Work Practices

A LARGE BODY of theoretical research in economics models firms' choices of employment practices. For example, a number of studies model the choice of compensation practices, such as profit sharing, efficiency wages, piece rates, team rewards, or other pay-for-productivity plans. Other work focuses not on compensation practices but on other work practices, such as the use of work teams, screening of workers, and sharing of financial information with workers.[1] Finally, other studies model the adoption of clusters of practices rather than individual practices.[2] These models typically explain the observed variation in firms' work practices by pointing to differences in factors, such as the cost of observing employee effort, the separability of employee effort, the separability of employee tasks on the job, or the relative value of quality versus quantity in the profit function of each firm.

In this paper we conduct an empirical investigation of the adoption of new work practices in a unique data set. The data set contains

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1. For reviews of recent models in this stream of literature, see Lazear (1991, 1992).
2. See especially Holmstrom and Milgrom (1994); Milgrom and Roberts (1993); Kandel and Lazear (1992); and Baker, Gibbons, and Murphy (1994).

longitudinal information on thirty-six production lines in the steel industry, lines that produce the same product with very comparable technologies. Due to the homogeneity of the production technology in the sample, we are able to exclude from consideration many of the possible drivers of the choice of work practices, such as differences in the cost of observing effort levels or the separability of tasks on the job, which are likely to be the same across lines in this sample. The sample, which was assembled through personal visits to plants, accounts for most existing facilities of this kind in the United States.

Historically, employment practices in many manufacturing establishments could be characterized by narrowly defined jobs, seniority-based promotion rules, and strict supervision by foremen, but that set of observed practices is now slowly changing. More recently, managers of many manufacturing establishments have been espousing very different employment practices that emphasize flexibility in job assignments, employee participation in work teams, employee problem solving, and open communication between managers and workers. In prior work we establish evidence that clusters of the newer work practices lead to substantially higher levels of productivity in this sample of steel production lines.[3] Given the similarity of the production lines and their products, the question naturally arises: why haven't more lines adopted these new work practice innovations that appear to have such strong effects on productivity?

To address this question, we focus on the costs of adopting new work practices in modeling adoption. Because of the similarity of the lines, the expected revenue gains from adopting the new practices should be similar across lines in this sample. This suggests that the limited adoption of the productivity-enhancing practices must largely pertain to differences in the costs of adoption. The costs of adoption include the costs of gathering information about new work practices and their effects on performance and the costs of overcoming the resistance to new work practices among managers and employees with long histories under more traditional work practices.

Estimates from the model of the adoption of innovative work practices reveal several clear empirical patterns. First, there are large birth effects. The youngest plants are considerably more likely to have the

3. Ichniowski, Shaw, and Prennushi (1993).

new, productivity-enhancing, workplace innovations. Furthermore, work practices, including the older more traditional work practices that are associated with the lowest levels of productivity, persist for long periods of time. However, the analysis does reveal certain conditions under which old lines will adopt the newer work practice innovations. These conditions include the threat of plant shutdown, often coupled with the introduction of new managers who support the philosophy of new work practices.

The paper is organized as follows. First, we briefly describe the sample of production lines and the data on employment practices. We then review theoretical models and empirical evidence that work practices should be adopted in clusters because of complementarities among work practices; we also summarize past results that document significant productivity advantages associated with sets of the new work practices. Given the estimated productivity advantages of the new work practices, we take up the question of why more of these production lines do not have the most productive work practices. Our model of the adoption of work practice innovations emphasizes the costs of switching employment practices. We then develop the empirical model of the adoption of work practices and present empirical results. Finally, we review evidence from interviews to provide a richer interpretation of the factors that determine the adoption of work practices.

Sample Design and Data

The sample for this study comes from the steel industry. Observations in the sample are not steel companies, divisions of steel companies, or even steel mills. Rather, each observation is a single production line within a mill—one very specific kind of steel finishing line. The production process for each of these finishing lines is the same. A line accepts large rolls, or coils, of cold-rolled steel as input. The coil is unrolled into the line so that a long sheet of steel threads its way through the finishing process. Once a coil is completely unrolled, the end of the coil at the entry end of the line is welded to the start of a new coil. The production process is therefore continuous. The strip of finished steel coming off the exit end of the line is rolled back into coils and then cut. Large integrated steel mills can have from one to four of these finishing lines, while some smaller companies operate only a few standalone lines. Most lines are manned by seven or eight operators.

Of approximately sixty finishing lines of this kind in the United States, we personally visited forty-five lines owned by twenty-one different companies. During each visit, which lasted from one to three days, we conducted interviews and toured the production lines. The sample includes all but one of the large integrated steel companies. During these visits and through follow-up phone calls, we collected data on the employment practices at each line, details of the machinery, quality and productivity measures, and other factors that are used to estimate a model of adoption of work practices in these lines. In total, the sample contains up to 2,190 monthly observations on thirty-six of these production lines that provided operating data, or on average a little more than five years of monthly data from the mid-1980s to early 1990s on the thirty-six lines.

Data on Human Resource Management Practices

The data on employment practices, which we also refer to as human resource management (HRM) practices, were gathered at each site by administering a standardized, but open-ended, interview protocol with human resource managers, labor relations managers, operations managers of the finishing lines, superintendents, line workers, and union representatives in organized lines. In this way we overcame the limitation of prior research, which typically relied on a single informant per organization, often through mail surveys. In addition, the responses regarding HRM practices refer to the specific production line under study, not to an entire plant. Finally, the information from our on-site interviews is supplemented with primary source records from personnel files, personnel manuals, collective bargaining agreements, and other documents.

From these sources we construct an extensive set of dummy variables for each line in each month to describe the lines' HRM practices. These variables measure practices in all major HRM policy areas, including recruiting and selection, incentive compensation, team-based work organization, flexible job assignment, employment security, training, and communication procedures. A representative list of thirteen HRM variables is shown in table 1 along with definitions of the variables.

These data on HRM practices will be used to construct the dependent variables in the empirical models of the adoption of work practices. One approach would be to examine individual HRM practices, such as incentive pay or the use of teams, as separate dependent variables. However, recent theoretical and empirical work suggests that this approach will be misleading since firms often adopt clusters of related HRM policies and not individual practices in isolation.[4] Before describing the specific measures we construct to represent the overall environment of HRM practices in these lines, we discuss the theoretical work that argues that work practices will often be adopted in clusters. We then review data on the distribution of HRM practices in our sample.

Theories of Complementarity among HRM Practices

Several recent theoretical studies on incentive contracts argue that HRM practices are often adopted in clusters rather than individually. Three of these studies describe reasons for complementarities among work practices that may be particularly applicable to our sample of manufacturing operations.

Complementary Practices to Elicit Workers' Ideas

To achieve high levels of productivity, it is often necessary to elicit employees' ideas for improving productivity. Milgrom and Roberts argue that systems of multiple HRM practices are most likely to accomplish this objective.[5] Employees often possess detailed knowledge that management does not have about the production process. While problem-solving teams have been developed to help elicit this kind of knowledge, employment security is a necessary complement to these teams because workers are concerned that their ideas for improving productivity will jeopardize their own jobs or those of their co-workers. Milgrom and Roberts argue further that employment security will in turn be complementary with a number of other work practices. A system of complemen-

4. For theoretical models of work practice complementarities, see especially Holmstrom and Milgrom (1994). In addition to our own empirical work on the productivity effects of clusters of work practices (Ichniowski, Shaw, and Prennushi, 1993), see recent studies by MacDuffie (1995) and Huselid (1995).

5. Milgrom and Roberts (1993).

Table 1. Definition of Human Resource Management (HRM) Variables

HRM practice	*Variable name*	*Mean*[a]	*Dummy variable description*
1. *Incentive pay*			
a. Profit sharing	*PROF SHARE*	0.700	Is there a company profit-sharing plan covering the line workers?
b. Line incentives	*INCENT*	0.186	Are operators covered by a ''nontraditional'' incentive pay plan that applies across shifts of workers and that is sensitive to quality as well as quantity aspects of output?
2. *Recruiting and selection*			
a. Selective screen	*HI SCREEN*	0.085	To hire new workers was an extensive selection procedure used, including tests for personality traits needed for cooperative team environments and efforts to set clear expectations about required work behaviors of the new workers?
3. *Work teams*			
a. High participation	*HI TEAM*	0.237	Are a majority of operators involved in formal or informal work teams or other related problem-solving activities?
b. Multiple teams	*MULTI TEAM*	0.130	Do operators participate in more than one problem-solving team?
c. Formal teams	*FORMAL TEAM*	0.335	Are operators organized into formal work teams (either on the line or for the purpose of problem-solving activities) according to an established policy with at least some operators involved in team activities?
4. *Employment security*			
a. Employment security	*SECUR POL*	0.288	Has the company committed to a goal of long-term employment security and offered employees a pledge of employment security?
5. *Flexible job assignment*			
a. Job rotation	*ROTATE*	0.079	Do operators rotate across jobs or tasks on the line?

6. *Skills and knowledge*			
a. High train	*HI TRAIN*	0.134	Have all operators on the line received off-the-job training?
b. Low train	*LO TRAIN*	0.208	Have at least some operators received off-the-job training?
7. *Labor-management communications*			
a. Share financial information	*INFOSHAR*	0.566	Are operators and union representatives, if any, provided with financial information on a regular basis?
b. Meet workers	*MEET WRKR*	0.508	Do line managers meet off-line with operators to discuss issues of concern, including issues related to performance and quality?
c. Meet union	*MEETU*	0.224	Do operators or union representatives and managers meet often to discuss concerns and cooperate in finding solutions to issues?

Source: Authors' calculations based on sample of steel production lines.

a. The mean for the main sample of N = 2,190 line-months. For the *MEETU* variable, we assign nonunion lines a value of 1 because these lines meet regularly with workers. The mean of this variable among the sample of union observations is 0.153.

tary practices to elicit workers' productivity-improving ideas includes work teams, employment security, flexibility in job assignments, and additional training to provide workers with the necessary skills to be productive in multiple job assignments.

Complementary Practices to Overcome Free Riding

In many manufacturing settings, incentives are paid only to groups, rather than to individuals, so free riding can be a problem. Kandel and Lazear show that group incentives can stimulate higher performance if group incentives are coupled with several other HRM practices that help address free-rider problems.[6] First, they suggest that firms need to adopt rigorous selection procedures and extensive indoctrination efforts when hiring workers in order to sort out those who would be likely to free ride; firms also need to establish norms of behavior that inhibit shirking by workers. Second, when group incentives are used, team meetings can be just as important for providing opportunities for workers to monitor each other as they are for working on specific tasks that might occur in teams. According to Kandel and Lazear, HRM practices that are complementary inputs into the production function of certain firms include group-based pay incentives, careful screening and indoctrination, and regular meetings among groups or teams of workers.

Complementary Practices to Make Subjective Appraisals of Workers Effective

Many compensation schemes tie workers' pay to at most one variable, such as quantity of output, thereby undermining long-run profits that can depend on other factors as well, such as quality of output. Multiple HRM practices can help make compensation schemes that incorporate multiple dimensions of performance more effective. Some valued dimensions of a firm's product may be difficult to measure, and they may depend on equally difficult-to-measure aspects of employees' behavior, such as their innovation, dependability, cooperation, and initiative. According to Baker, Gibbons, and Murphy, "subjective incentive contracts," such as personnel evaluations of the subjective aspects of workers' contributions, are under certain circumstances com-

6. Kandel and Lazear (1992).

plementary with incentive pay schemes based on objective measures of performance, such as physical output.[7] For example, the HRM practice of problem-solving teams, which requires employees to demonstrate cooperation and initiative, can be complementary with objective incentive pay plans based on more easily measured outputs.

Implications

These theories imply that HRM practices should be distributed in clusters of related practices. This point is important because it argues that the dependent HRM variables for this study should measure the overall HRM environment as determined by groups of work practices. The theories also imply that specific clusters of HRM practices may be better suited for eliciting worker ideas and initiative and overcoming free-rider problems (and thereby produce higher levels of productivity) than other combinations of practices. Any productivity differentials attributable to certain HRM practices would be an important source of revenues motivating firms to adopt these practices. We now turn to evidence from the sample of steel production lines on these two predictions.

The Distribution of HRM Practices and Evidence of Clusters of Complementary Practices

Table 1 presented information on the distributions of a representative sample of thirteen HRM variables. Even in this very homogeneous sample of steel production lines, some HRM practices (such as those in item 7 to enhance labor-management communication) were much more common than others (such as those in items 2 and 5 to screen workers carefully and to improve job flexibility).

Table 2 shows a different aspect of the distribution of HRM practices across lines. It presents data on the combinations of HRM practices found in the thirty-six lines as of January 1992.

The distributions in table 2 suggest that HRM practices do tend to be adopted in clusters. In particular, the four combinations of practices displayed in columns 1, 7, 8, and 9 account for a full two-thirds of the

7. Baker, Gibbons, and Murphy (1994).

Table 2. The Distribution of HRM Practice Combinations

		Combinations of HRM practices in 1992								
HRM practice	*Variable name*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
1. Selective screening	*HI SCREEN*	yes	no	no	no	no	no	no	no	no
2. Regular skills training for some or all workers	*LO TRAIN* or *HI TRAIN*	yes	yes	yes	yes	yes	no	no	no	no
3a. Work teams with high levels of employee participation	*HI TEAM* or *MULTI TEAM*	yes	yes	yes	yes	yes	no	no	no	no
3b. Work teams with low levels of employee involvement	*FORMAL TEAM* without *HI TEAM* or *MULTI TEAM*	yes	no	no	no	no	yes	yes	yes	no
4. Multi-attribute incentive pay	*INCENT*	yes	yes	no	no	no	no	no	no	no
5. Job flexibility through job rotation or reduced job classifications	*ROTATE* or *LO JOBCLASS*	yes	no	no	yes	yes	yes	no	no	no
6. Employment security	*SECUR POL*	yes	no	no	no	yes	yes	yes	no	no
7. Regular labor-management meetings and/or financial information sharing	*MEET WRKR* or *INFOSHAR*	yes	yes	yes	yes	yes	yes	yes	yes	no
Percentage of sample in category in 1992		11.1	5.6	8.3	8.3	5.6	2.8	19.4	22.2	16.7

Source: Authors' calculations based on sample of steel production lines. N = 36 production lines in January 1992.

HRM combinations found in all lines in 1992. In the sample 16.7 percent have none of the HRM practices listed in table 2 (column 9). Another very distinctive group, which accounts for an additional 11.1 percent of the sample, has all of the HRM policies (table 2, column 1). The two other combinations of HRM policies shown in columns 7 and 8 of table 2 account for another 42 percent of the sample. In these observations there is always some labor-management communication process and a formal work team policy with low levels of employee participation in teams. The only difference between these two groups is that one has an employment security policy and the other does not.

The combinations of HRM practices in the remaining third of the lines (table 2, columns 2 to 6) are not so neatly described, but they still show distinctive features. The lines in these columns always have labor-management communication processes (item 7). In all cases but one they have team policies with high levels of employee participation (item 3a) and regular skills training (item 2). However, the lines vary widely in the extent to which they adopt line-specific incentive pay plans, flexible job assignment policies, careful screening policies, and employment security.

Another way of documenting the complementarity of practices is to show that individual practices are positively correlated with each other. Table 3 shows simple bivariate correlations among the HRM practices described in tables 1 and 2. Table 3 contains one observation for each different HRM combination experienced by a line. For the thirty-six production lines in our sample, there are fifty-four different HRM combinations, indicating that the thirty-six lines experienced eighteen combinations besides those for 1992 shown in table 2. As expected from the limited number of HRM practice combinations shown in table 2, table 3 reveals many significant positive correlations among the HRM practices.

The distribution of HRM practices described in tables 2 and 3 shows that certain HRM practices are adopted only in the presence of certain other HRM practices. The distribution also shows strong positive correlations between many practices. Both patterns are consistent with the idea that HRM practices are complementary. Based on this evidence, the dependent variables in the empirical analysis of adoption should measure the overall HRM environment because firms often adopt at one time a set of related work practices.

Table 3. Correlations among HRM Practices

HRM practices	*PROF SHARE* (1)	*INCENT* (2)	*HI SCREEN* (3)	*HI TEAM* (4)	*FORMAL TEAM* (5)
Incentive pay					
1. *PROF SHARE*	1.0	.111	−.088	−.031	.116***
2. *INCENT*		1.0	.456***	.503***	.289***
Recruiting and selection					
3. *HI SCREEN*			1.0	.436***	.000
Work teams					
4. *HI TEAM*				1.0	.324***
5. *FORMAL TEAM*					1.0
6. *MULTI TEAM*					
Employment security					
7. *SECUR POL*					
Flexible job assignment					
8. *ROTATE*					
Skills and knowledge					
9. *HI TRAIN*					
10. *LO TRAIN*					
Labor-management communication					
11. *INFOSHAR*					
12. *MEET WRKR*					
13. *MEETU*					

Measuring Complementary Clusters of HRM Practices

In order to create useful measures of clusters of HRM practices, we grouped HRM practices using several different procedures.[8] Each procedure weights the individual HRM practices for each line and creates a unidimensional index, which we label *HRINDEX*, with values that are specific to each line at each point in time.[9] For example, the Nominate statistical procedure produces an index that ranges from −1 to 1,

8. The four grouping procedures are Nominate scaling, Guttman scaling, multidimensional scaling, and scaling according to a simple additive index of the HRM dummy variables. For a description of the first three scaling algorithms, see Poole and Rosenthal (1991), and Ghiselli, Campbell, and Zedeck (1981). See our previous work (Ichniowski, Shaw, and Prennushi, 1993) for details of the application of these procedures to the data on HRM practices from this study's sample.

9. To provide as rich a description of the production lines' overall HRM environments as possible, we consider a larger set of HRM variables than is listed in table 1. We introduce twenty-six practices into the grouping procedures. In addition to the

Table 3. Continued

MULTI TEAM (6)	*SECUR POL (7)*	*ROTATE (8)*	*HI TRAIN (9)*	*LO TRAIN (10)*	*INFOSHAR (11)*	*MEET WRKR (12)*	*MEETU (13)*
.052	.299**	−.166	.084	−.031	.427***	.049	.021
.343**	.063	.372***	.302**	.412***	.041	.325**	.265*
.229*	.384***	.397***	.208	.436***	.283**	.226*	.529***
.526***	.031	.492***	.578***	.645***	.243*	.434***	.434***
.477***	.194	.192	.506***	.487***	.185	.418***	.178
1.0	−.152	.177	.706***	.630***	.191	.087	.319**
	1.0	.032	−.084	−.053	.659***	.429***	.352***
		1.0	.473***	.352***	.064	.255*	.137
			1.0	.779***	−.046	.121	.172
				1.0	.000	.185	.336**
					1.0	.418***	.356***
						1.0	.244*
							1.0

Source: Authors' calculations based on sample of steel production lines. N = 54 observations with one observation for each distinct HRM environment experienced by a line. The number of observations on different HRM environments per finishing line ranges from 1 to 3. For the *MEETU* variable, we assign nonunion lines a value of 1 because of regular meetings with workers. For variable definitions, see table 1.

*Significant at .10 level.

**Significant at .05 level.

***Significant at .01 level.

where lines with an index value of 1 have the most innovative set of HR practices, and lines with an *HRINDEX* of −1 have the least innovative set of practices. We then take the *HRINDEX* created by each alternative grouping procedure and look for natural breakpoints in its values. Observations are grouped into four clusters based on these breakpoints. We find that the grouping procedures produce very highly correlated HR indices, and they also produce nearly identical groupings of observations into the four HRM clusters. Thus, the alternative sta-

thirteen HRM practices listed in table 1, we consider dummy variables for intermediate levels of worker screening; training in problem-solving skills; the presence of informal work teams assembled on an "as needed" basis; support of the local union for team activities; employee participation in updating work procedures; salary-based, pay-for-knowledge plans; and combined job classifications between operators and maintenance workers.

tistical procedures produce remarkably similar results. This is because the simple patterns of HRM practices revealed in table 2 show lines progressing through a series of practices from no innovative work practices (column 9) to having all possible innovative work practices (column 1). The *HRINDEX* is a measure of the extent of this progression.

Table 4 describes the four clusters of HRM practices identified consistently by all of the grouping procedures. These clusters of HRM practices, or "HRM systems," subsume the more detailed categories of HRM practice combinations shown in table 2. At one extreme are lines with none of the innovative practices. This category (labeled HRM System 4 in table 4, column 4) matches column 9 in table 2. It accounts for 17 percent of all lines in 1992 and for 37 percent of all observations in the panel sample of monthly observations. At the other extreme are lines with all of the innovative practices. This category (labeled HRM System 1 in table 4, column 1) corresponds to lines in column 1 of table 2 and accounts for 11 percent of all lines in 1992 and 9 percent of the panel sample.

Lines having HRM System 3 have practices that are similar to HRM System 4 except that the lines with System 3 always have some form of labor-management communication, either regular information sharing or labor-management meetings (items 7a and b), and some formal work team policy with low levels of employee participation (items 3a, 3b, and c). This category corresponds to lines in columns 7 and 8 in table 2, and accounts for 42 percent of all lines in 1992 and 41 percent of the panel sample. The remaining lines have HRM System 2, which consists of many but not all of the innovative HRM practices. Regular skills training and high levels of employee participation in teams are hallmarks that differentiate it from HRM systems 3 and 4. This system matches columns 2 through 6 in table 2 and accounts for 31 percent of all lines in 1992 and 12 percent of the panel sample.

In addition to these categorical HRM System variables, we measure the overall HRM environment of the lines using the unidimensional *HRINDEX* created by the scaling procedures. The last item of table 4 shows the distribution of the *HRINDEX* score for each of the four HRM systems as generated by the Nominate scaling procedure. The scaling procedure generates an index score for each observation that ranges from a low of -1 in HRM System 4 lines with none of the innovative practices to a high of $+1$ in HRM System 1 lines with all of the

Table 4. Production Lines with a Specific HRM Practice within Four HRM System Categories

Percent

Practices in seven HRM policy areas	*HRM System 1*	*HRM System 2*	*HRM System 3*	*HRM System 4*
1. Incentive pay				
a. Multi-attribute line incentives	100	31	0	0
2. Recruiting and selection				
a. Selective screening	100	15	0	0
3. Work teams				
a. High participation in teams	100	85	10	0
b. Workers in multiple teams	100	62	0	0
c. Some formal teams	100	100	100	0
4. Employment security				
a. Employment security	100	23	48	0
5. Flexible job assignment				
a. Job rotation	50	15	3	0
b. Reduced job classifications	100	40	4	0
6. Skills training				
a. High training, all workers	100	69	0	0
b. Low training, some workers	100	92	7	0
7. Labor-management communication				
a. Share financial information	100	54	62	0
b. Meet workers	100	77	72	0
Ranges of *HRINDEX*	1.00	0.72 to 0.86	0.29 to 0.63	−1.0 to 0.12

Source: Authors' calculations based on sample of steel production lines. N = 54 for each distinct HRM environment experienced by a line. The variables are defined in table 1. The percentages refer to the percentage of the lines in that system having the practice.

innovative practices.[10] Lines with HRM systems 2 or 3 have intermediate values of this HRM index, but in no case is there any overlap in the index values for lines in different HRM systems.

The Effects of HRM Practices on Productivity

Productivity gains from adopting innovative sets of HRM practices provide further evidence of complementarities. Evidence on the productivity effects of HRM practices provides an important context for this study's empirical work on the adoption of work practices. In particular, any systematic productivity effects attributable to certain HRM practices, or certain combinations of HRM practices, would increase the revenues of lines and therefore be an important reason for lines to adopt those practices. In our previous work we analyzed the effects of these HRM practices on productivity in this sample of steel finishing lines, and we review those findings here to provide a necessary background for the empirical work on adoption.

The homogeneous sample of steel finishing lines allowed us to develop particularly convincing estimates of the productivity effects of HRM practices. In particular, the homogeneous sample eliminates the effects of many factors that would confound the productivity comparisons in more broadly defined samples. Furthermore, after touring each line and collecting detailed operating data, we were able to develop a model of the production function that captured the specific details of this steel finishing process.[11] The model is estimated using the panel sample of 2,190 monthly observations on the performance of the thirty-six steel finishing lines.

The dependent variable of primary interest in the analysis is the uptime of the line—the percentage of time that the line is scheduled to operate that it is actually running. The average monthly uptime is 91.9 percent in this sample with a standard deviation of 4.4 percentage

10. Because the scaling procedures consider a longer list of HRM variables than is presented in tables 1 or 2, the HRM index values for lines in System 4 are not all -1. One or two of these other HRM variables will be present in the HRM System 4 lines, raising their index values above -1.

11. The empirical specification included seventeen controls that measure differences in detailed aspects of the lines' machinery. It also included controls for the vintage of the line, for learning curve effects during startup periods of the line, for quality of steel material inputs, and for the maintenance practices of the line.

Table 5. Estimated Productivity Effects of HRM Practices

HRM practices	*Auto-regressive*[a] *(1)*	*Fixed effects*[b] *(2)*
HRM System 1	0.062* (0.007)	. . .
HRM System 2	0.036* (0.008)	0.035* (0.008)
HRM System 3	0.024* (0.005)	0.025* (0.005)
ρ	0.390* (0.020)	0.317* (0.020)
R^2	0.497	0.068
SSR	2.117	2.262

Source: Authors' calculations based on sample of steel finishing lines. The dependent variable is *UPTIME*. The mean of *UPTIME* is 0.92. N = 2,190. Standard errors are in parentheses. The first-order serial correlation coefficient is ρ.

*Significant at .01 level.

a. Control variables are number of years the line has been operating and years squared; the year the line was built and year built squared; dummy for startup periods indicated by first twelve months of operations and 1-to-12 time trend for month of startup operation; 1-to-5 index of quality of steel input; number of annual eight-hour scheduled maintenance shifts; dummy for type of customer; maximum speed of line and speed squared; maximum width of the line and width squared; nine dummies to indicate specific pieces of equipment from start to finish of the line and a measure of the age of one piece of equipment at end of the line; a dummy to indicate high and low levels of computer control of line operations; and a variable to measure six-month periods from the date that any new major pieces of equipment are introduced.

b. Control variables are age of line and age squared; dummy for startup periods indicated by first twelve months of operations and 1-to-12 time trend for month of startup operation; 1-to-5 index of quality of steel input; age of the end-of-the-line piece of equipment; a variable to measure six-month periods from the date that any new major pieces of equipment are introduced; and estimated changes in the value of capital due to the introdution of any new major pieces of machinery from the date the new equipment was installed.

points, and it ranges from a low of 39.8 percent to a high of 99.6 percent. The independent variables of primary interest are the categorical HRM System variables presented in table 4.

Table 5 summarizes the main results of the productivity analyses from our previous work. When the four HRM System dummy variables are included in the detailed model of productivity of these finishing lines, the results shown in column 1 of table 5 are obtained. The theories reviewed earlier in this section argue that the highest levels of productivity will be found in plants with a specific combination of HRM practices that includes careful screening, use of incentive pay covering multiple dimensions of performance, team-based work organization, job flexibility, employment security, and training in multiple tasks. The results support this prediction: lines with HRM System 1 that have all of these innovative work practices do in fact have the highest productivity.

The results also reveal a clear hierarchy of productivity effects. They indicate that moving from the traditional HRM System 4 to System 3 raises uptime 2 percentage points (from about 88 percent to 90.5 percent), moving to System 2 raises uptime about one more percentage point (to 91.6 percent), and moving to System 1 raises uptime another 3.6 percentage points (to about 94.2 percent).[12]

The productivity effects of the HRM systems were also re-estimated in models that included controls for line-specific fixed effects. The results of these fixed-effects models are shown in column 2 of table 5. While no line switched into HRM System 1 (and thus there is no estimate for the effect of HRM System 1 in the fixed-effects model), the fixed-effects results are nearly identical to the results for full panel estimates in column 1.[13] According to the results of the fixed-effects models, productivity increases are observed with exactly the same workers and the same capital equipment after lines adopt systems of newer practices.

Productivity effects of the magnitude shown in table 5 are economically important to these lines and are likely to be sizable for all lines in this sample. Using detailed cost data available from one line, we conservatively estimate that the impact of moving from a traditional HRM System to the most innovative is approximately $172,980 per month in net revenues from increased uptime.[14] Permanent increases in monthly revenues of this magnitude would be substantial over the life of one of these production lines, amounting to more than $20 million in ten years. Because the lines in this sample are so similar and the jobs done by the production workers are so similar, there is every reason to

12. The coefficients on the HRM System variables are statistically different from one another. For example, an F-test rejects the hypothesis that the coefficients on the three HRM systems are not different from one another ($F(2,2168) = 6.2$). Other F-tests indicate that any pair of coefficients are statistically different from one another.

13. An F-test supports the hypothesis that the coefficients on the variables for HRM systems 2 and 3 in the fixed-effect model are significantly different from one another ($F(1,2169) = 4.07$).

14. While lines produce no output during delays, they still incur fixed costs and any variable costs, such as labor costs, that are typically paid during down time. Fixed costs are substantial, with hourly fixed cost charges exceeding $5,000 in some lines. The figure of $172,980 for the increase in net revenue is based on an estimate of $27,900 for the impact of a 1 percent increase in uptime. This is a conservative estimate. It is based on conservative estimates of the costs incurred during delays and conservative estimates of the profit margin on a ton of steel. This estimate is also net of the costs directly associated with the HRM practices that comprise the innovative HRM systems.

believe that all lines would benefit substantially from the use of innovative HRM practices. Our plant tours displayed concrete evidence that the uptime gains from introducing innovative practices tend to arise from production workers' improvements in the monitoring of the production line and from their suggestions for improving the operation of the line. Though we show below that newer lines have been more likely to adopt innovative practices, it is clear from the fixed-effects results (and plant tours) that the older lines that changed practices experienced substantial gains from innovative practices.

Theoretical Framework for Modeling the Adoption of Innovative HRM Practices

The pattern of results shows that innovative systems of HRM practices have large effects on productivity and on revenues. This raises a fundamental question. Why have these new productivity-enhancing HRM systems not been adopted more widely?[15] We turn now to a model of adoption of practices and pay particular attention to adoption costs. These costs might explain the limited diffusion of the productivity-enhancing practices across the sample of steel finishing lines.

In modeling the adoption of HRM practices, we assume that the state of knowledge regarding the optimal types of HRM practices evolves over time in a manner that is analogous to technological change. For example, as U.S. managers and the business and academic press gave more attention to the "Japanese model" of labor relations and to models of HRM in new nonunion companies, evidence about and use of innovative HRM practices in the United States increased in the 1970s and

15. In table 5 the estimates of the productivity and related revenue effects due to systems of newer HRM practices may be biased upward. The estimated productivity differentials due to HRM systems would be biased if, for example, unmeasured aspects of the capital equipment or the work forces made the newer HRM systems a more appropriate choice for certain lines. Despite the homogeneity of the sample and the careful specification of control variables in the productivity model, this explanation might reasonably hold for the table 5, column 1, specification. However, we do not find this a plausible explanation for the results of the fixed-effects models, which show that a line operating with exactly the same equipment and workers improves its productivity after it adopts newer HRM systems. Our on-site research revealed no evidence of other time-varying factors correlated with the adoption of HRM practices that might account for the improvement in productivity among these HRM system changers.

1980s. We consider the practices that are often used to characterize the ''Japanese'' or contemporary ''nonunion'' models to be examples of innovations in the management of labor resources. In other words, the state of knowledge of optimal practices is not static, and thus the adoption of different types of practices should change over time.

Thus, we assume that managerial innovations are analogous to technological innovations, and we model the adoption of an innovative HRM system as an investment decision analogous to a decision to invest in physical capital. At time t, firm i will invest in a cluster of HRM practices denoted by subscript j, when the expected internal rate of return, ER_{ijt}, from investing exceeds the firm's minimum required return, R_{ijt}. A firm adopts innovative practice j if $ER_{ijt} > R_{ijt}$, so the adoption function is

$$(1) \qquad \begin{aligned} I_{ijt} &= 1 \text{ if } ER_{ijt} - R_{ijt} > 0 \\ \text{else } I_{ijt} &= 0. \end{aligned}$$

Both ER and R are specific to the firm and vary over time. The expected internal rate of return, ER, is the discount rate that sets the discounted stream of expected future returns equal to the stream of expected future income had the innovation not taken place, given the relevant time horizon of the firm. Thus, the rate of return will be a function of the stream of future revenues from innovating minus the fixed costs.[16]

For simplicity, we specify $ER_{ijt} - R_{ijt}$ as a linear function of explanatory variables $\mathbf{X}$, with unknown parameters β_j,

16. This simple model of adoption disregards several complicating factors. With up-front sunk costs involved in investments in new HRM practices, the threshold condition for deciding not to engage in certain HRM practices will differ from the condition in equation 1 for adopting the new practices. The sunk costs introduce a zone of hysteresis into the investment decisions (Bresnahan and Reiss, 1993). When there is uncertainty about future returns on the investment in new work practices, when the investment is likely to be reversed, or when future HRM practice decisions depend upon current adoption decisions, then the adoption decision should be modeled differently. A dynamic programming model that incorporates the uncertain effects of future decisions on the current decision would be more appropriate. While these factors may be important, we present a simpler theoretical model that does not focus on these factors but is sufficient to motivate our empirical examination of age-related costs that impede investments in new work practices.

$$
\begin{aligned}
I_{ijt} &= 1 \text{ if } \beta_j' \mathbf{X}_{it} + \epsilon_{ijt} > 0 \\
&\quad \text{for } ER_{ijt} - R_{ijt} = \beta_j' \mathbf{X}_{it} + \epsilon_{ijt} \\
\text{else } I_{ijt} &= 0
\end{aligned}
\tag{2}
$$

where the **X** variables include the variables that influence the costs of innovating, the returns to innovating, and the minimum required return.

In this study's sample of steel finishing lines, many factors that affect the costs and revenues associated with adopting HRM practices are held constant because of the similarity of the production units. Factors considered in many theories to be important determinants of firms' decisions to adopt certain HRM practices (such as the ease of monitoring workers, the ability to separate individual performance from team performance, or the impact of product quality on the firm's profits) will vary little across the observations in this sample. Similarly, the productivity effects associated with clusters of new work practices are likely to be increases in productivity that any line in the sample would enjoy if it were to adopt the new practices. Given the homogeneous sample, it seems reasonable to pay particular attention to possible differences in the costs of adopting the new productivity-enhancing work practices. What costs might be responsible for their limited adoption? We introduce two perspectives on this question: a "macro" perspective on organizational change and a "micro" perspective on workers' propensities to embrace changes in work practices.

Information and Search Costs with Complementary HRM Practices

First we consider the macro perspective on organizational change. In the case of systems with various complementary elements, some argue that firms that choose such systems are likely to get "locked into" their initial choices and thus not achieve maximum efficiency.[17] For example, Levinthal shows that the profit function of the firm will have multiple local optima when its organizational policies are complementary. The multipeaked profit function, in turn, makes it likely that a firm's organizational form at birth will have a lasting impact on its

17. See, for example, David (1985); Katz and Shapiro (1994); Levinthal (1994); and Milgrom and Roberts (1993).

future form. In particular, if firms do not have perfect information about which policies are the best choices, they need to search for better alternatives. Then, because of the complementarities among the firm's organizational policies, local searches that involve changes in one or two individual policies will not improve profitability, and so a firm's policies are likely to persist.

Two predictions emerge from models of organizational change such as Levinthal's. First, a firm's initial HRM practices will have a lasting impact on its future practices when complementarities among practices are important and when the firm's information about the performance effects of work practices is incomplete.[18] Older plants that started operating with traditional work practices years before any plants in the United States attempted newer systems of work organization would not be likely to adopt new work practices if information on the performance effects of work practices was imperfect and search for this type of information was costly. Second, as information about the expected productivity and revenue effects of work practices improves over time, more firms should begin to adopt the newer work practices.

Costs Associated with Workers' Resistance to Changing Policies

In considering the micro perspective on sources of resistance to change from production and managerial employees, we introduce the notion of "relationship-specific" skills. Relationship-specific skills include the firm-specific (or line-specific) skills that are needed to run the particular production line and also the less tangible kinds of knowledge and skills related to the interpersonal and authority relationships implicit in a given set of work practices. For example, under the system of more "traditional" work practices with narrow job classification, wage-based pay, and extensive supervision, workers will be accustomed to foremen who monitor their behavior and give instructions. In team-based work organizations with flexible job assignments, workers will interact more with other production workers and make more decisions on their own or with team members. The role of supervisors is also likely to be different in the two environments. In the traditional environment, supervisors will be production specialists who give in-

18. This prediction matches the observation of Stinchcombe (1965) that organizational policies of a firm are "imprinted" at the time of founding.

structions, while in the innovative environment, managerial workers will need to be skilled at getting individuals to work together in groups.

Traditional and innovative environments require very different skills. Many of the skills for the innovative systems can be learned, but they require renewed effort and investments on the part of the workers accustomed to the traditional work environments. Though firms will pay for the direct costs of these investments (such as costs of new training or time off from the job), workers bear the costs of expending personal effort. Workers may resist bearing these costs for several reasons. They may have a shorter time horizon than the firm has. They may also doubt the personal return to the investment. Or they may suspect they will lose their jobs if reorganization accompanies the new work practices. These factors can also apply to managerial employees; they, too, may be reluctant to invest in new relationship-specific skills. Employees who have grown accustomed to work habits and relationships through years of working in a traditional environment may resist investing in the new skills needed under a different set of work practices.[19]

The "Birth" of New Work Systems versus Changes to Existing Work Systems

Adoption of new work practices can occur under two fundamentally different conditions: when a firm makes its decision about its initial set of work practices at its "birth" and when a firm makes a decision to change an established set of work practices. New plants should be at a considerable advantage because the costs of adoption of the innovative practices should be lower for them than for an older plant that might try to change its set of traditional practices.

New plants have lower adoption costs for several reasons. First, the initial costs of gathering information about work practices that a plant incurs when it is designing its original policies should be lower for more recently opened plants as more firms gain experience with the newer

19. As one example of the employees' relationship-specific skills, Cyert and March (1963) argue that because of managers' bounded rationality, managers often develop rules of thumb. Managers rely on these rules, and they become difficult to change. For more discussion of the role of managers' resistance to changing work practices, see Cockburn and Henderson (1994). For a related concept of relationship-specific skills applied to organizational form (such as the vertical integration of firms), see Williamson (1986) and his references.

practices. Second, new plants that are choosing an initial set of work practices do not face the costs associated with employee resistance to changing pre-existing practices.

Summary

Both the macro perspective on organizational change and the micro perspective on workers' resistance to change predict that age-related factors will impede change in work practices and that new plants at their time of startup will have a marked advantage in adopting innovative work practices relative to older plants. These age-related impediments to changing work practices and the advantage of new plants in adopting the innovative work practices are the focus of the empirical model and analysis.

The Empirical Specification of the Adoption Model

As discussed above, we take two different approaches to measuring the production lines' overall set of work practices in specifying the dependent variable in the adoption models.

Specification of the Dependent HRM Variable

In one specification the dependent variable in equation 2 is the set of four categorical variables, HRM System 1 through HRM System 4. When this specification of the dependent variable is used, adoption equations will be estimated as a multinomial logit model.[20] The alternative dependent variable is the *HRINDEX*, based on the score from the Nominate scaling procedure, which varies from -1 to 1 as the set of practices selected by the line move from least innovative to most

20. An alternative approach to estimating a model of the adoption of HRM Systems would be to estimate hazard rate models of the probability of exiting a system given the duration in the system. The monthly data used here would be ideal for such an estimation. However, we do not estimate hazard rate models because the majority of the spells would be left or right censored since there are few multiple changes of systems. The majority of the older lines would have left censored spells of long duration that could not be used in the estimation.

innovative. Using the *HRINDEX* as the dependent variable, H_{it}, the linear adoption model becomes

(3) $$H_{it} = \alpha'\mathbf{X}_{it} + e_{it}.$$ [21]

The two alternative dependent variables make different assumptions regarding the effects of independent variables on the adoption of HRM practices. Use of the *HRINDEX* imposes the restriction that the independent variables have equivalent linear effects on the adoption of HRM practices across the entire -1 to $+1$ range of this dependent variable. Multinomial logit models using the four categorical HRM system dummies as the dependent variable allow the independent variables to have different effects on the choice of the different HRM systems. The *HRINDEX* has the advantage of capturing more limited changes in the HRM environment than is captured by the systems dummies because small changes in individual practices will often change the value of the *HRINDEX* but not change the system choice of the lines. In the empirical work the *HRINDEX* will be used most often because the linear specification for the dependent variable facilitates the estimation of alternative adoption models, such as those with lagged dependent variables and fixed effects.[22]

Independent Variables Measuring the Costs of Adopting HRM Innovations

The independent variables that affect the adoption of new HRM practices include those factors that influence the costs of innovating and the returns to innovating.[23] However, by restricting the sample to one very specific type of production technology, many sources of variation that might exist in more broadly defined samples should be eliminated.

21. The j subscripts of equation 2 disappear in equation 3 because the j sets of alternative practices vary within the linear measurement of the *HRINDEX* as the dependent variable, instead of across alternative choices as in equation 2.

22. Because the *HRINDEX* ranges from -1 to $+1$, Tobit estimation of equation 3 should be considered (with mass-points at -1 and at $+1$). In estimating the models of table 9, we found little difference between linear OLS versus Tobit estimation, largely because there are very few observations located near the mass-points. Thus, for ease of estimating fixed effects and lagged dependent variable models, we begin by presenting OLS results in table 9.

23. In the steel industry, differences in minimum required returns in equation 1 are not likely to exist or are not readily measured by the available proxies.

In our review of factors that might cause variations in the expected costs and revenues of adopting new HRM practices, we focus on those factors that are likely to vary in this narrow sample.

The introduction of innovative HRM practices can be impeded by the costs of overcoming resistance from workers who have made past investments in relationship-specific skills that are valuable only under their current work practices. New practices would require investments in new skills. The proxies we will use for relationship-specific skills are tenure variables: the years of tenure of the CEO in his current job (*CTENURE*); the years of tenure of the line manager in his current job, where the line manager is the area operations manager in charge of the steel lines studied (*MTENURE*); the years of tenure of the plant-level HR manager in his current job (*HRTENURE*); and the years of tenure of the local union president in his current job as president (*UTENURE*).

All tenure variables are measured in years, with monthly variation in tenure measured as fractions of years. Other than the CEO tenure variable, these variables measure tenure at the specific production line rather than tenure in the firm or steel mill. For the production workers, only age data are available rather than line tenure data. The workers' average age (*AGE*) is likely to vary less than line tenure because newer lines tend to hire older workers (for their valued experience in steel making). These age and tenure variables should have negative effects on the propensity to introduce innovative HRM practices, because relationship-specific investments are correlated with tenure.

Resistance to making new investments in relationship-specific skills could be weakened, thus diminishing the costs of innovation, if workers and managers are persuaded that the firm may go out of business if innovations to raise performance are not implemented. Examples of persuasive information come from threat effects—from credible threats that the line may be shut down and the jobs lost. Three variables are used to measure threat effects: the percentage of the plant that has been shut down and remains shut down (*PSHUT*); the common use of layoffs in the plant (*PLAYOFF*); and the number of steel mills permanently shut down in the surrounding area (*SSHUT*).[24]

24. For example, the value of *PSHUT* is permanently 0.3 from the date that 30 percent of the plant is shut down, and *SSHUT* persists comparably. The introduction of less permanent shutdown effects made little difference, though more temporary shut-

Innovations should also increase over time, as innovations in HRM practices become available and as they become known to managers because of the experimentation and learning in other firms.[25] A time trend also may raise adoptions as information regarding expected revenues improves.[26] For this effect, a *TIME* trend is included in the regressions, where *TIME* is the current monthly date (for example, 90.25 for March of 1990).

Finally, the fixed costs of adopting innovative work practices, including the costs of gathering and evaluating information on the success of new work practices, will be a smaller percentage of revenues for larger firms, and thus larger firms may be more likely to introduce innovations. Larger firms may have scale economies in the learning, implementation, and operation of work practice innovations because they have more trained staff to assist in the adoption and use of HRM practices, and more plants in which to experiment with adoption.[27] Lines that are part of large firms in this sample are those that are owned by the integrated steel-producing companies. The dummy variable *INTEG* is therefore the proxy for firm size.

Variables Affecting the Revenues from Adopting HRM Innovations

Given the similarity of these lines, many factors that could cause differences in the expected revenues from adopting new work practices will be held constant in this sample. In particular, factors such as the ability to observe workers' output and effort should be similar across observations because production technologies are so comparable. Similarly, the expected revenue gains because of productivity effects from adopting new practices should be comparable across lines. Nevertheless, to test for possible differences in expected productivity gains, we

down effects could arise over the long run beyond our data period (further into the 1990s) as the shutdowns of the 1980s become more distant.

25. See David (1985); Quirmbach (1986); and Stoneman (1981) for time effects in technological innovations.

26. This statement assumes that the innovative HRM practices are truly profitable and that it takes time for firms to assess this condition, relative to unprofitable alternatives. This framework follows the disequilibrium models of Griliches (1957). Griliches assumes that firms will increasingly adopt an innovation as they learn more about the profitability of the innovation.

27. See Mansfield (1968); Davies (1979); Rose and Joskow (1990); and Oster (1982).

will control for technology variables in the regressions that will serve as reduced form proxies for expected uptime gains.[28]

A few factors vary in this sample and may affect the expected revenue gains from adopting new work practices. First, differences in the local product market characteristics of these finishing lines may affect the expected revenue gains due to new HRM practices. Firms that anticipate growth in their product market may have the most to gain from adopting new productivity-enhancing work practices.[29] Firms anticipating increased competition may also have higher expected returns if they expect to lose market share without the new practices. There may be a short-term first-mover advantage if it takes time for other firms to adopt new work practices, and customers form explicit or implicit contractual relationships with those producers who adopt the performance-enhancing practices first. On the other hand, in highly competitive markets, the gains to adoption may be short-lived as rival firms mimic innovation.[30] Game-theoretic models that consider the advantages to early adoption of new practices, such as first-mover advantages, produce no consensus on the direction of the effects of market structure characteristics on expected revenues.[31] Thus, factors such as market share, anticipated market growth, and market concentration may affect expected rates of return from adopting new practices, but the direction of these effects is unclear a priori.

Two variables measure differences in the market structures and competitive conditions of these lines: the percentage of the line's product sold in a national rather than regional market (*NATIONAL*), and the number of new competitors that have permanently entered the line's market during the sample period (*NUMCOMP*). *NUMCOMP* ranges from 0 to 3 at each point in time as reported by line managers.

Lines with longer time horizons can expect to enjoy productivity benefits for longer time periods and thus increase adoption. Since lines

28. We do not introduce current uptime in the adoption regressions because current uptime is not a proxy for the *expected productivity gains* to introducing innovative HRM practices; the technological variables should be superior in comparing expected gains across lines.

29. See Barzel (1968).

30. See Rose and Joskow (1990).

31. See Reinganum (1981); Quirmbach (1986); Hannan and McDowell (1984); Fundenberg and Tirole (1985); and Kamien and Schwartz (1982) for models of technological innovations.

with credible shutdown threats are likely to have shorter time horizons than lines that are not threatened (such as newer lines), shutdown variables described above may also be proxies for shorter expected time horizons. These variables are the percentage of the plant shut down, the use of layoffs, and the number of steel mill shutdowns nearby.

Lines with better information about HRM innovations and their expected revenues will be more likely to adopt them. Managers with more experience may have better contacts in the industry and more information about the use and effects of innovations, thus innovations could rise with all measures of tenure rather than fall as suggested in the cost analysis. This may be especially true for the line manager's years of experience in the industry (*MEXPER*).[32] Large firm size may also increase the adoption of new work practices because larger firms have better access to information on innovations and can spread the information-gathering costs across greater revenues, thus increasing adoption for integrated producers (*INTEG*).[33]

Finally, adoption decisions should also depend on the firm's expectation of how the revenue gains from adoption will be shared between firms and workers. Some firms may face a greater probability that workers or their union representatives will extract returns associated with improved productivity. A dummy variable for union presence (*UNION*) and a dummy variable to indicate a more adversarial labor-management relationship characterized by high employee grievance rates (*GRIEV*) are proxies for these effects.

Table 6 summarizes the predicted effects of the cost and revenue variables on the adoption of HRM innovations. Note that many variables have uncertain signs because they enter the cost and revenue calculations in different ways. This is especially true of the variables that serve as proxies for threat effects. When threat effects serve as proxies for short time horizons, they are expected to lower the adoption of innovative HRM practices, whereas when they serve as proxies for cost effects, they are expected to have positive effects on adoption because

32. Using industry-level data, Mansfield (1968) found no support for the proposition that younger managers are more likely to introduce technological innovations than are managers with more years of experience in the industry. Managerial education also may enter the equation, however. In the steel industry, that education is quite homogeneous: managers have a bachelor's degree in engineering or metallurgy.

33. See Mansfield (1968); Davies (1979); and Jensen (1988).

Table 6. Hypothesized Effects of Variables on Adoptions

	Hypothesized effects on adoption operating through:	
Variables	*Expected revenues of innovating*	*Expected costs of innovating*
Production workers' age (*AGE*)		−
CEO's tenure (*CTENURE*)	+	−
Line manager's tenure (*MTENURE*)	+	−
HR manager's tenure (*HRTENURE*)	+	−
Union president's tenure (*UTENURE*)	+	−
Manager's industry experience (*MEXPER*)	+	−
Percentage of plant shut down (*PSHUT*)	−	+
Current plant layoffs (*PLAYOFF*)	−	+
Time (*TIME*)	+	+
Large integrated firm (*INTEG*)	+	−
National market (*NATIONAL*)	?	
Competitive market (*NUMCOMP*)	?	+
Unionization (*UNION, GRIEV*)	−	−

Source: Authors' calculations based on sample of steel production lines.

they convince workers to overcome their resistance to adoption. Combining these effects, we find that the expected impact of threat effects is uncertain. Based on our plant interviews, these are very plausible predictions: some plants overcame shutdown threats and introduced innovations, and some did not.

Empirical Estimates of the Adoption Equation

Before estimates from the adoption model are presented, we first show the distribution of HRM systems for three different categories of plants: "new" lines opened since 1983; "reconstituted" lines that began operations before 1983 but were shut down and then reopened by new owners; and "old" lines that have been in continuous operation since well before 1983. These distributions offer preliminary evidence about the effects of age-related costs of changing HRM practices and about the advantages of new plants in adopting innovative practices at the time they start operations. New lines begin operations with brand new technologies and new complements of managers and employees. Reconstituted plants typically have very old technologies, but they will

Table 7. Distribution of Lines by HRM System
Percent

Type of line	*System 1*	*System 2*	*System 3*	*System 4*
Newly built lines[a]	43	57	0	0
Reconstituted lines[b]	20	40	20	20
Old lines[c]	0	12	57	31

Source: Authors' calculations based on sample of steel production lines. The percentages refer to the percentage of the lines in that row of the table with the given system. The row percentages therefore sum to 100 percent. N = 54 for one observation for each distinct HRM environment experienced by a line.
a. Those constructed after 1983.
b. Those that reopened under new ownership in the 1980s.
c. Lines that are not new or reconstituted.

hire many new workers or managers when new owners purchase and reopen the line (or hire a subset of carefully screened former workers). Old lines have old technologies with low rates of turnover among employees who have long tenures at their work sites.

Table 7 shows clear differences in the distributions of HRM systems for these three different categories of lines. All the new lines have either System 1 or System 2. Reconstituted lines, despite their older capital, have a significant portion of their lines in Systems 1 or 2. Virtually all old lines have either System 3 or System 4 lines.

New lines appear to have a clear advantage in adopting new practices. Some new lines have made minor changes in work practices since they opened, but in no case did these lines make enough work practice changes to switch their HRM system. Reconstituted lines, despite having technologies as old as those found in the "older" lines, have a much greater representation in HRM systems 1 and 2 than do the older lines, perhaps indicating that when a line reopens with new managers and workers, the costs of changing practices are lower than they are in lines continuously operated by the same managers and workers. Finally, old lines almost always have the traditional work practices that dominate HRM systems 3 and 4. At the same time there is still considerable variation in the HRM systems within each category. To help identify the sources of this variation, and to investigate whether the advantage of new lines in adopting innovative work systems is due more to differences in the age of workers, the tenure of managers, general improvements over time in information about the practices, or other factors, we now estimate the adoption models of equations 2 and 3.

Estimates from Multivariate Adoption Models

The adoption equations will be estimated by ordinary least squares when the linear *HRINDEX* is the dependent variable, and by multinomial logit models when the four HRM system dummies are the dependent variables. Table 8 presents means and standard deviations of the various dependent and independent variables used in the adoption model.

Table 9 reports results from ordinary least squares (OLS) models in which *HRINDEX* is the dependent variable.[34] Regardless of the combination of control variables used in the model, the results show that the worker age variables and manager tenure variables have a negative effect on adoption of new work practices. The average production worker age (*AGE*) and three tenure variables—line manager tenure (*MTENURE*), HR manager tenure (*HRTENURE*), and local union president tenure (*UTENURE*)—all have negative effects. The lone exception is the tenure of the CEO, which is positively correlated with adoption of new practices.

Even in the column 3 specification that adds detailed controls for various types of equipment on the lines (equipment that is determined in large part by the vintage of the line), these age and tenure effects persist. Where the work force is older and local managers have been working on the line for more years, the value of *HRINDEX* is lower, indicating the presence of more traditional work practices.

These negative effects of age and tenure variables on adoption may be from "birth effects," with new lines more likely to adopt new work practices (as suggested in table 7), or they may be from the effects of age variables within subsamples of old and new lines. (For example, old lines with old work forces may be more resistant to change than old lines with

34. Note that the sample includes a large number of monthly observations on each line under the assumption that each line, in principle, could change its HRM practices in any given month, so that each month of data provides important information on the probability of adoption. For most lines, the dependent variable changes little over time, though the right-hand-side variables change much more. Note also that the standard errors in the simple OLS models are biased due to serial correlation, but the serial correlation is representative of omitted fixed effects and lagged dependent variables that are introduced shortly. Any attempt to introduce a serial correlation correction now will approximate the fixed-effects estimation because the correlation coefficient will be close to one. Note finally that the sample size falls to 2,081 due to some missing data on right-hand-side tenure variables in the adoption regressions.

young work forces.) Before investigating in more detail the source of the estimated negative effects of age and tenure, we briefly review the effects of other independent variables in the model.

—Threat effects are measured by the percentage of the plant that is shutdown (*PSHUT*), the use of layoffs in the plant (*PLAYOFF*), and the number of steel mills nearby that have been shut down (*SSHUT*). Threat effects could lower adoption because they might indicate a shorter time horizon for receiving the returns from the work practice innovations, or they could raise adoption by galvanizing the work force into making needed changes to attempt to avoid shutdown. There appears to be evidence for both effects. *PLAYOFF* and *SSHUT* have consistently positive effects on adoption, although the latter is not significantly different from zero in some specifications. The effect of *PSHUT* varies with *AGE* of the production work force, but in general the coefficients on the *PSHUT* and *PSHUT*AGE* variables imply that lines have lower values of the *HRINDEX* when *PSHUT* is zero than when *PSHUT* is nonzero, even when lines have relatively older work forces.[35]

—The line manager's experience in the industry, *MEXPER*, has a strong negative effect on adoption, thus the investment in relationship-specific skills overcomes any positive information effects that older managers might have.

—A time trend is held constant in the regressions and is universally positive. It may represent unexplained improvements in HRM practices over time because of improved knowledge.

—The effects of the two variables measuring market competition are significant but with opposite signs. A large number of closely competing lines (*NUMCOMP*) is positively correlated with *HRINDEX*, but lines that compete in broader geographical markets, indicated by the dummy *NATIONAL*, have much lower values of *HRINDEX*.

—We hypothesized that adoption would be lower in union environ-

35. While the average value of *PSHUT* for the whole sample is 0.06 (see table 8), the average of *PSHUT* for those lines with partial plant shutdowns is about 0.35. For plant shutdowns of this magnitude, a one standard deviation increase in the age of the work force (that is, five years) would amount to a difference of about 0.3 in the *HRINDEX* relative to the effect of such a plant shutdown for an average age work force. Nevertheless, values of the coefficients on the *PSHUT* and *PSHUT*AGE* variables indicate that the *HRINDEX* is higher when there are no plant shutdowns (*PSHUT* = 0) than when *PSHUT* is nonzero—even for relatively old work forces.

Table 8. Variable Definitions and Means

Variable name	*Variable definition*	*Full sample (N = 2,081)*	*Old lines (N = 1,591)*[a]	*New lines (N = 490)*[b]
HRINDEX	Index of HRM practices	0.26 (0.57)	0.13 (0.58)	0.71 (0.28)
AGE	Average of workers' ages	45.07 (5.00)	46.63 (4.34)	40.02 (3.41)
CTENURE	Tenure of CEO	5.15 (3.90)	5.54 (4.15)	3.87 (2.55)
MTENURE	Tenure of line manager	3.51 (2.71)	4.04 (2.79)	1.80 (1.45)
HRTENURE	Tenure of HR manager (plant level)	3.91 (3.25)	4.62 (3.27)	1.61 (1.81)
UTENURE	Tenure of union president	4.14 (3.77)	4.16 (3.08)	4.09 (5.46)
MEXPER	Industry experience of line manager	25.83 (8.08)	27.07 (6.73)	21.83 (10.45)
NATIONAL	Product for national market (= 1)	0.21 (0.16)	0.23 (0.16)	0.15 (0.11)
NUMCOMP	Number of new competitors (0 to 3)	0.61 (0.88)	0.69 (0.95)	0.33 (0.52)
PLAYOFF	History of plant layoffs (= 1)	0.63 (0.48)	0.68 (0.47)	0.15 (0.17)

PSHUT	Percentage of plant shut down	0.06 (0.14)	0.08 (0.16)	0.01 (0.03)
SSHUT	Number of surrounding steel mills shut down (0 to 5)	0.80 (1.54)	1.05 (1.69)	0.02 (0.15)
INTEG	Line is part of integrated mill (= 1)	0.79 (0.40)	0.98 (0.14)	0.08 (0.40)
UNION	Union mill (= 1)	0.90 (0.29)	0.98 (0.14)	0.66 (0.47)
STARTUP	Year current firm owners began operating line	66.55 (12.46)	60.98 (8.29)	84.64 (2.75)
NEW	Startup after 1983 (= 1)	0.24 (0.40)	0.0	1.0
BUILT	Year line was built	63.07 (10.03)	59.81 (6.97)	73.65 (11.09)
GRIEV	Number of grievances less than 12 this year (= 1)	0.53 (0.50)	0.60 (0.49)	0.29 (0.45)
*PSHUT*NEWMGR*	Value of *PSHUT* for lines with *MTENURE* less than 3.	0.02 (0.10)	0.03 (0.12)	0
*PSHUT*NEWHR*	Value of *PSHUT* for lines with *HRTENURE* less than 3.	0.01 (0.06)	0.01 (0.07)	0

Source: Authors' calculations based on sample of steel production lines. Standard deviations are in parentheses.
a. Began operating with the current owner before 1984.
b. Began operating with the current owner after 1983.

Table 9. Linear Model of HRM Adoption Practices

	OLS		
Variable name	*1*	*2*	*3*
TIME	0.030*	0.031*	0.031*
	(0.005)	(0.005)	(0.005)
AGE	−0.213*	−0.123*	−0.091*
	(0.041)	(0.043)	(0.041)
$(AGE)^2$	0.0023*	0.0014*	0.0011*
	(0.0005)	(0.0005)	(0.0004)
CTENURE	0.042*	0.049*	0.024*
	(0.012)	(0.012)	(0.011)
$(CTENURE)^2$	−0.0017	−0.0024*	−0.0008
	(0.0011)	(0.0010)	(0.0010)
MTENURE	−0.099*	−0.091*	−0.047*
	(0.014)	(0.014)	(0.013)
$(MTENURE)^2$	0.0097*	0.0093*	0.0057*
	(0.0014)	(0.0014)	(0.0013)
HRTENURE	−0.023	−0.025	0.011
	(0.014)	(0.014)	(0.013)
$(HRTENURE)^2$	0.0022	0.0025	0.0005
	(0.0013)	(0.0013)	(0.0012)
UTENURE	−0.083*	−0.059*	−0.104*
	(0.009)	(0.009)	(0.008)
$(UTENURE)^2$	0.0043*	0.0028*	0.0041*
	(0.0005)	(0.0006)	(0.0005)
MEXPER	−0.016*	−0.013*	−0.016*
	(0.002)	(0.002)	(0.002)
NATIONAL	−1.23*	−1.26	−0.778*
	(0.09)	(0.86)	(0.086)
NUMCOMP	0.179*	0.175*	0.141*
	(0.019)	(0.018)	(0.017)
PLAYOFF	0.094*	0.093*	−0.052
	(0.031)	(0.030)	(0.031)
PSHUT	−4.91*	−3.57*	−8.90*
	(0.84)	(0.86)	(0.79)
*PSHUT*AGE*	0.100*	0.076*	0.166*
	(0.017)	(0.018)	(0.016)
SSHUT	0.021	0.014*	0.036*
	(0.011)	(0.010)	(0.010)
INTEG	. . .	−0.249*	. . .
		(0.038)	
Technology controls	no	no	yes
N	2,081	2,081	2,081
R^2	0.301	0.315	0.465
SSR	481.51	472.10	368.80

Source: Authors' calculations based on sample of steel production lines. Standard errors are in parentheses. Variables are defined in table 8. The dependent variable is *HRINDEX*.

*Significant at the .01 level.

ments because unions might extract some of the returns from the investment. Unions also may resist changes in the union-management relationship. Union president tenure and resistance were discussed above. What about a union effect per se? Because these data are from plants that are 92 percent unionized, it is hard to test such a hypothesis. In results not shown in the tables, we find that a union dummy does have a negative effect. When a *UNION* dummy variable is added to the column 1 specification, its coefficient is −0.141 with a standard error of 0.051.[36]

—The theoretical framework posits positive firm size effects on adoption. Our integrated producers are the large producers. The coefficient on *INTEG* is negative and significant (see table 9, column 2), indicating that adoption rates are lower for integrated producers, not higher as models of access to information and capital and cost spreading would suggest.[37]

—A set of capital equipment variables introduced in the column 3 model of table 9 has significant adoption effects, though they are likely to be correlated with age effects that will be discussed shortly.

The results from the multinomial logit models, presented in table 10, are generally consistent with these results. The shutdown and market structure effects have essentially the same impact as they did in the *HRINDEX* models, and while the tenure effects are generally negative, the less restricted estimates of the logit model relative to the linear *HRINDEX* model produce some changes in sign for three tenure coefficients.[38]

36. We also investigated the effects of a variable measuring whether the plant had high or low grievance rates (*GRIEV*). The estimated effect is negative and very large in the various specifications. For example, when *GRIEV* is added to the column 1 specification, its coefficient is −0.412 with a standard error of (.033). The grievance rate variable is likely to be endogenously determined by HRM systems. New HRM systems such as systems 1 and 2 are able to reduce grievance activity through other means of labor-management communication and problem solving.

37. In the steel industry it is likely that factors inhibiting change are correlated with large firm size: large firms have shorter time horizons due to their old plants, they have more resistance from their older workers, and they are liquidity constrained. Therefore, large firms have a tendency to make marginal adjustments in practices. Oster (1982) also found negative firm size effects for technology adoption in the steel industry, though most other studies of technology adoption—such as Rose and Joskow (1990); Mansfield (1968); and Davies (1979)—have found positive firm size effects on adoption.

38. One difference between these logit results and those using the *HRINDEX* is that

Table 10. Multinomial Logit Models of HRM System Adoption

	1 HRM Choices		*2 HRM Choices*		*3 HRM Choices*		
Variable name	*System H*	*System 3*	*System H*	*System 3*	*System 1*	*System 2*	*System 3*
TIME	0.608*	0.393*	0.825*	0.424*	−0.123	1.12*	0.402*
	(0.051)	(0.040)	(0.064)	(0.042)	(0.085)	(0.09)	(0.041)
AGE	−4.71*	−3.75*	−1.349*	−2.292*	−8.57*	−3.10*	−3.76*
	(0.37)	(0.33)	(0.456)	(0.363)	(1.03)	(0.51)	(0.33)
$(AGE)^2$	0.053*	0.042*	0.014*	0.025*	0.083*	0.040*	0.042*
	(0.004)	(0.004)	(0.005)	(0.004)	(0.011)	(0.005)	(0.004)
MTENURE	−0.390	0.905*	−0.127	0.855*	−2.38*	0.268	0.782*
	(0.203)	(0.149)	(0.250)	(0.150)	(0.039)	(0.344)	(0.144)
$(MTENURE)^2$	−0.054	−0.131*	−0.124*	−0.119*	0.143*	−0.261*	−0.121*
	(0.029)	(0.018)	(0.043)	(0.018)	(0.048)	(0.066)	(0.017)
HRTENURE	−0.376*	−0.304*	0.207	−0.263*	5.10*	−1.76*	−0.206
	(0.123)	(0.099)	(0.156)	(0.110)	(0.52)	(0.22)	(0.106)
$(HRTENURE)^2$	0.030*	0.005	−0.072*	−0.004	−0.510*	0.152*	−0.005
	(0.011)	(0.018)	(0.016)	(0.010)	(0.516)	(0.019)	(0.009)
UTENURE	−0.542*	0.434*	−0.736*	0.457*	−1.87*	−0.565*	0.445*
	(0.088)	(0.068)	(0.102)	(0.073)	(0.27)	(0.124)	(0.070)
$(UTENURE)^2$	0.031*	−0.023*	0.039*	−0.025*	0.050*	0.033*	−0.026*
	(0.006)	(0.005)	(0.006)	(0.005)	(0.023)	(0.007)	(0.005)
MEXPER	−0.195*	−0.179*	−0.263*	−0.186*	−0.392*	−0.200*	−0.162*
	(0.016)	(0.014)	(0.019)	(0.014)	(0.031)	(0.023)	(0.014)

NATIONAL	−4.03*	−6.95*	−6.78*	−8.50*	0.612	−3.67*	−6.94*
	(0.56)	(0.64)	(0.68)	(0.72)	(1.03)	(0.68)	(0.64)
NUMCOMP	0.435*	−0.607*	−0.031	−0.714*	−0.140	0.317	−0.557*
	(0.141)	(0.117)	(0.170)	(0.129)	(0.251)	(0.171)	(0.115)
PSHUT	. . .	. . .	−118.4*	−32.05*	. . .	. . .	. . .
			(11.9)	(9.34)			
*PSHUT*AGE*	. . .	. . .	2.71*	0.780*	. . .	. . .	. . .
			(0.27)	(0.219)			
Log likelihood	−1,146.4		−994.9		−1,035.7		

Source: Authors' calculations based on sample of steel production lines. Standard errors are in parentheses. Variables are defined in table 8. The HRM System choices 1, 2, 3, or H are made relative to the base choice of traditional System 4. System H combines Systems 1 and 2.

*Significant at the .01 level.

The "Birth Effects" in the Adoption of Innovative Practices

The descriptive data in table 7 show that new firms are much more likely to adopt innovative HRM practices than are older firms. The negative effects of age and tenure variables on adoption shown in tables 9 and 10 in part reflect these "birth effects," because "new" lines (those opened since 1983) have managers with lower levels of tenure and work forces with lower average ages, and these *TENURE* and *AGE* variables had negative effects on the adoption of new work practices in the table 9 and 10 results. Table 11 presents results from additional adoption models to examine the importance of any *TENURE* and *AGE* effects that are independent of the birth effects.

The models in columns 1 to 3 of table 11 replicate the column 1 specification in table 9, but they also include three additional variables—*NEW*, *STARTUP*, AND *BUILT*. *NEW* is a dummy variable for lines that started operating after 1983, or that restarted operations under new owners after 1983. The cutoff of 1983 is chosen because the birth of lines in this sample tends to cluster in the 1950s to 1960s and in the mid-1980s to 1990s. Only two lines are born between these periods (one in 1972 and one in 1981). *STARTUP* ranges from 48 to 91 and measures the year the line began operating under its current ownership, which is not necessarily the date the line was built. Finally, *BUILT* is the date the line first produced steel under its initial owners. *BUILT* and *STARTUP* will be equal except in the case of the "reconstituted" lines that were shut down but were later reopened by new owners.

In the column 1 model in table 11, the *NEW* variable is very significant and very sizable. The coefficient on *NEW* implies that the new lines raise the value of *HRINDEX* by 0.79 relative to the old lines. This is a large effect amounting to an increase of 1.39 standard deviations of the dependent variable. While the large effect of *NEW* controls for the average difference in the *HRINDEX* between old and new lines, there is still evidence of some negative effects of tenure variables on

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the tenure coefficients on *MTENURE* and *UTENURE* become positive for the choice of System 3 relative to System 4. Note that table 10 contains two sets of System choices. In logit number 3, we model the alternative choices of the four HRM Systems described above—Systems 1 through 4. In logits 1 and 2 we combine Systems 1 and 2 into one "System H" (for highly innovative). Systems 1 and 2 are collapsed into H because the threat variables do not change for the small groups of lines in System 1, so the specification containing these variables is not identified until System 2 is combined with System 1.

adoption within new and old lines, though these effects are much smaller than they were in the table 9 models without the *NEW* variable.

The column 2 model in table 11 adds the *STARTUP* variable to the column 1 specification. The average *STARTUP* dates for new and old lines are 1985 and 1961, respectively. The coefficient on *STARTUP* implies a difference of 0.86 in the values of the *HRINDEX* for lines that have *STARTUP* dates that are twenty-four years apart. The inclusion of *STARTUP* dramatically reduces the coefficient on *NEW*. Furthermore, in this column 2 specification, the *TIME* trend and almost all age and tenure variables have insignificant coefficients.

The *STARTUP* variable is clearly a key variable. We believe it measures important tenure effects that are not captured in the tenure and age variables described thus far (though positively correlated with them). In particular, the tenure variables measure the managers' tenures on the current line, not tenure with the current plant or tenure with the firm, yet the latter might often be a better measure of the manager's investment in relationship-specific skills. Even more important, *STARTUP* is an excellent proxy for the tenure of the production workers at the plant, because once production workers are hired into steel plants, they have very low turnover rates. Thus, an early *STARTUP* date is synonymous with very high worker tenure relative to a recent startup date. The significance of *STARTUP* reflects two factors. First, firms have adopted more innovative practices over time. Second, these practices have changed little over time within firms because of the buildup of relationship-specific skills.

Importantly, the *STARTUP* variable is not simply a proxy for the effects of newer technology on the adoption of HRM practices. The column 3 specification that includes the variable *BUILT* makes this point. Again, *BUILT* refers to the date the line was first built and differs from *STARTUP* in the case of reconstituted lines. The coefficient on *BUILT* is significant but small in magnitude relative to the effect of *STARTUP*. The inclusion of *BUILT* has virtually no effect on the magnitude or significance of the coefficient on the *STARTUP* variable.

The Persistence of HRM Practices

The importance of the *STARTUP* variable is symptomatic of persistence in HRM practices over time within lines. As described earlier,

Table 11. Linear Model of HRM Adoption

	Entire sample				Old lines[a]	New lines[b]
Variable name	*1*	2	3	4	5	6
TIME	0.013*	−0.005	−0.008	0.0003	−0.013*	. . .
	(0.004)	(0.004)	(0.004)	(0.0006)	(0.004)	
AGE	−0.005	−0.017	−0.007	0.003	−0.013	−0.060
	(0.037)	(0.033)	(0.032)	(0.005)	(0.046)	(0.010)
AGE^2	0.0004	0.0004	0.0004	−0.00004	0.0005	0.0009
	(0.0004)	(0.0004)	(0.0004)	(0.00006)	(0.0006)	(0.0006)
CTENURE	0.031*	0.028*	0.039*	0.003	0.071*	−0.032*
	(0.011)	(0.010)	(0.010)	(0.002)	(0.001)	(0.010)
(CTENURE)^2	−0.0006	−0.0010	−0.0004	−0.0002	−0.0032*	0.0004
	(0.0010)	(0.0080)	(0.0008)	(0.0001)	(0.0009)	(0.0010)
MTENURE	−0.034*	−0.010	−0.0003	0.00006	. . .	. . .
	(0.013)	(0.011)	(0.0115)	(0.0018)		
(MTENURE)^2	0.0045*	0.0027	0.0018	−0.0004	. . .	. . .
	(0.0013)	(0.0011)	(0.0011)	(0.0002)		
HRTENURE	0.0054	0.021	0.012	0.0013	. . .	. . .
	(0.0127)	(0.011)	(0.011)	(0.018)		
(HRTENURE)^2	0.0023	−0.0002	0.0007	−0.0002	. . .	. . .
	(0.0012)	(0.0010)	(0.0010)	(0.0002)		
UTENURE	−0.020*	−0.021*	−0.026*	−0.0014	. . .	. . .
	(0.008)	(0.007)	(0.007)	(0.0011)		
(UTENURE)^2	0.0002	0.0003	0.0004	0.00004	. . .	. . .
	(0.005)	(0.0004)	(0.0004)	(0.00006)		
MEXPER	−0.014*	−0.016*	−0.019*	−0.0005*	−0.024*	−0.0018
	(0.001)	(0.001)	(0.001)	(0.0002)	(0.002)	(0.0009)

NATIONAL	−1.18*	−1.19*	−1.08*	−0.028*	−1.26*	0.325*
	(0.08)	(0.07)	(0.07)	(0.011)	(0.08)	(0.060)
NUMCOMP	0.262*	0.173*	0.188*	−0.0004	0.189*	0.132*
	(0.017)	(0.015)	(0.015)	(0.0002)	(0.015)	(0.012)
PLAYOFF	0.133*	0.126*	0.128*	0.0076	0.235*	−0.325*
	(0.027)	(0.023)	(0.024)	(0.0038)	(0.015)	(0.015)
PSHUT	−0.952	−3.05*	−3.88*	−0.033	−2.90*	−15.3*
	(0.765)	(0.67)	(0.66)	(0.103)	(0.65)	(4.2)
*PSHUT*AGE*	0.018	0.062*	0.075*	0.002	0.065*	0.305*
	(0.016)	(0.014)	(0.014)	(0.002)	(0.013)	(0.099)
SSHUT	−0.009	0.084*	0.090*	0.004*	0.090*	−0.136*
	(0.009)	(0.009)	(0.008)	(0.001)	(0.009)	(0.042)
NEW	0.792*	0.013*	. . .	. . .	. . .	. . .
	(0.033)	(0.006)				
STARTUP	. . .	0.036*	0.031*	0.0003	0.030*	0.024*
		(0.001)	(0.001)	(0.0002)	(0.002)	(0.003)
BUILT	. . .	. . .	0.009*	0.0001	. . .	. . .
			(0.002)	(0.0003)		
LAG *(HRINDEX)*	. . .	. . .	. . .	0.984*	. . .	. . .
				(0.003)		
N	2,081	2,081	2,081	2,046	1,591	490
R^2	0.447	0.577	0.584	0.989	0.539	0.848
SSR	380.89	291.75	286.94	. . .	. . .	. . .

Source: Authors' calculations based on sample of steel production lines. Standard errors are in parentheses. Variables are defined in table 8. The dependent variable is *HRINDEX*.
*Significant at the .01 level.
a. Began operating with the current owner before 1984.
b. Began operating with the current owner after 1983.

persistence in HRM practices is likely because it is costly to reinvest in relationship-specific skills and because it is costly to acquire the information necessary to make enough changes in HRM practices for a line to change its overall HRM system.

However, there are also likely to be other factors influencing transition costs that are not captured by the observed variables. For example, the macro explanation of limited adoption focuses on the slow acquisition of information, and the *TIME* variable is likely to be an imperfect proxy for this effect. Though the variables underlying these transition costs (such as the costs of information) cannot be perfectly measured, the theory would imply that the adjustment of human resource management practices occurs very slowly over time. This concept can be formalized in a simple stock adjustment model. Assume that the set of optimal HRM practices are H^*_{it} if transition costs that slow the speed of adjustment are omitted:

$$H^*_{it} = \Gamma \mathbf{Z}_{it} + v_{it}, \tag{4}$$

where the $\mathbf{Z}_{it}$ is equal to $\mathbf{X}_{it}$ of equation 3 after omitting short-term transition costs. In each period t the actual H_{it} will not adjust to the desired H^*_{it} but will instead move slowly relative to last period's H_{it-1}:

$$H_{it} - H_{it-1} = \delta(H^*_{it} - H_{it}). \tag{5}$$

Substituting for H^*_{it} from equation 4 and rearranging produces

$$H_{it} = \delta \Gamma \mathbf{Z}_{it} + (1 - \delta) H_{it-1} + \delta v_{it}. \tag{6}$$

Equation 6 implies that when short-term transition costs are unobserved, current H_{it} is a function of optimal H^*_{it} ($= \Gamma Z_{it} + v_{it}$). However, H_{it} does not adapt perfectly to the optimal practices because of transition costs that are captured by H_{it-1}. H_{it} therefore exhibits persistence. In addition, H_{it} will exhibit persistence because some lines already have their desired practices. For these lines, change will never be optimal, so H_{it-1} will be an excellent proxy for H^*_{it}.

The results of estimating equation 6, in column 4 of table 11, demonstrate very strong persistence: the coefficient on H_{it-1} is close to one, and coefficients on most other variables become insignificant. The persistence is likely to occur for two reasons: because few adjustments in practices are made from month to month and because for some lines such adjustments might never be optimal.[39]

The "Changers" in the Adoption of Innovative Practices

Having documented the persistence of the HRM practices, we ask the final question: who changes practices and why? In our data set about half the lines changed their practices over the sample period (though fewer changed their "system" of practices). What caused these lines to change?

To focus on changers, we estimate fixed-effects regressions for the sample of old lines (started up before 1984). We limit the sample to old lines because only they make sizable changes: new lines start up with new human resource practices and make little or no change to their initial set of practices.

The results in table 12 show that threat effects and market structure combine to predict change. The shutdown of steel plants nearby (as measured by *SSHUT*) positively predicts HRM innovation. And in some circumstances, the shutdown of parts of the plant (or *PSHUT*>0) predicts positive HRM change. Looking at the interactions between PSHUT and three other variables, we find that when parts of the plant are shut down, plants are more likely to change their HRM practices if they have an older work force, or if they have new line managers or new HR managers.

Offsetting these shutdown threats, an increase in the number of competitors in their market niche (*NUMCOMP*) tends to predict less change. In this case the increase in direct competition lowers the time horizon for returns to new investments in HRM practices and lowers the propensity to change that might otherwise arise from a threat effect that is not accompanied by an increase in direct competition.

Though shutdown threats do predict changes, they are not perfect predictors. The reason for this imperfect prediction comes from the theoretical model discussed above. A shutdown threat can mean either that dramatic action is needed to avert shutdown or that a shutdown is so likely that no action should be taken at all (because the time horizon for returns is short). It is likely that both effects occur simultaneously

39. The monthly frequency of the data clearly raises persistence. Annual data produce less persistence.

Table 12. Linear Model of HRM Adoption Practices for Old Lines

Variable name	Fixed-effects models (1)	Fixed-effects models (2)
CTENURE	0.0017 (0.0048)	0.0037 (0.0022)
(CTENURE)^2	0.0027* (0.0004)	0.0001 (0.0002)
MEXPER	0.013* (0.001)	0.0024* (0.0006)
NUMCOMP	−0.108* (0.007)	−0.025* (0.003)
PSHUT	−18.33* (1.16)	−4.50* (0.57)
*PSHUT*AGE*	0.334* (0.021)	0.083* (0.010)
*PSHUT*NEWMGR*	0.277* (0.044)	0.076* (0.021)
*PSHUT*NEWHR*	3.97* (0.016)	0.753* (0.084)
SSHUT	0.131* (0.005)	0.026* (0.003)
LAG *(HRINDEX)*	...	0.833* (0.010)
R^2	0.668	0.927
SSR	28.33	5.98

Source: Authors' calculations based on sample of steel production lines. Standard errors are in parentheses. Variables are defined in table 8. The dependent variable is *HRINDEX*. N = 1,591.
*Significant at .01 level.

and that workers and managers may not know which conditions prevail. In our field interviews we certainly heard support for both conditions (in which threat effects caused change and in which they stymied change). So, in our data, threat effects stimulate changes in some cases, and in other cases they do not.

There are a number of possible reasons for change that were not supported or could not be tested. For example, we find no effect of tenure variables on the propensity to change. That seems to be true for two reasons. First, this is a subsample of old lines, thus all have such high levels of "relationship-specific" investments that the differences between the lines in tenure cannot predict change. Second, if we added the new lines to the sample in the fixed effects, the regression results would not change since there were no big "changers" among the new lines. But the reason for the lack of change in new lines is not so much the buildup of relationship-specific skills as it is the fact that they began their lines with much more innovative practices and had less room for improvement.

We also found no effects of changing managers (when the change is not interacted with threat effects). As is evident in the mean tenure values of table 9, there is frequent turnover of managers in these lines and plants. Our interview evidence suggested that even when new managers do support the introduction of new HR practices in principle, they often feel they cannot overcome the resistance of the workers and frontline supervisors in implementing changes. Thus, dummy variables for new managers (less than three years tenure) had no direct impact on change. Practices are very persistent, as is evident in the lagged dependent variable coefficient in column 2 of table 12.[40]

Interpreting the Results Using Evidence from Field Interviews

The predominant mechanism for adopting innovative systems of HRM practices is through the birth of a new line, as is evident in the negative effects of the line age and employee tenure variables. Older lines that began operating in the 1950s and 1960s started with more traditional work practices. Through 1992, very few of these older lines

40. The coefficient on the lagged dependent variable falls in table 12 relative to the OLS model of table 11 because the table 11 OLS results do not control for fixed effects. The table 11 models therefore have greater month-to-month correlation in the dependent variable. In addition, the coefficient on the lagged dependent variable in the fixed-effects results could be downward biased because the lagged dependent variable is correlated with the lag in the residual that arises when differencing from the mean in fixed effects. One way of eliminating the bias is to first-difference the model and then instrument the lagged dependent variable with instruments of lag greater than one. When we instrumented in a first-differenced model, we found little change in the coefficient on the lagged dependent variable. The likely reasons that we find little bias are that the dependent variable changes little over time, and we have high levels of T (or observations per line) so that the correlation between the lagged dependent variable and one-month lagged residual plays a minor role (out of all T-lags in the fixed effect). Hsiao (1986, p. 74) shows that as T approaches infinity, the bias in the coefficient on the lagged dependent variable falls to zero in fixed effects.

made any major changes to their traditional practices. The older capital in these lines does not explain the persistence of the older practices, since lines with older equipment that shut down but later reopen under new owners will often adopt newer work practices.

Why then are most older firms ''stuck'' with more traditional work practices? One possibility is that a lack of information on optimal HRM policies causes firms to make marginal adjustments in their practices. These marginal changes will have very little effect on performance, which in turn may discourage firms from considering more extensive changes in their work practices. While this may provide part of the explanation, it cannot tell the whole story. The reason is that all new lines and most reconstituted lines choose innovative practices (HRM systems 1 or 2). This pattern should provide a signal to old lines that they should consider a ''leap'' to an entirely new set of practices. But old lines rarely make this leap. Old lines appear to be held back from making more extensive changes by resistance from workers and managers who have invested in the old work environment and do not wish to make new relationship-specific investments. Those firms that do change often do so during times of threatened job loss when new managers are brought in to make large-scale changes in the work environment.

During our field research at each of the sites in our sample, we conducted interviews about the HRM practices. We report here evidence from these interviews to provide a richer interpretation of the negative effects of line age and employee tenure on the adoption of innovative, productivity-enhancing, HRM practices.

Sources of Managers' Resistance in Old Lines

New forms of work organization move the locus of decision-making authority for many production matters away from managers and toward workers. Some plants refer to their teams as ''self-directed work teams.'' Local managers with the longest tenures have experience with more traditional work practices. Newer, more participatory forms of work organization would change the roles of these local-level managers. Because of their uncertainty about their roles under new forms of work organization, long-tenured managers oppose such changes at many sites. Managers at two lines indicated how foremen at their lines were concerned about any moves toward more participatory forms of work organization.

> Managers here wonder what their role in the [employee participation initiative] would be and whether it was an attempt to cut their jobs.

> Foremen here don't really understand their role in a more participatory work environment. One very real possibility to them was that the new environment meant no need for supervisors.

Sources of Union Representatives' Resistance in Old Lines

Interviews also indicated that the typical roles of local union officials under traditional HRM practices were not conducive to the philosophy embodied in the new HRM systems, raising the resistance to the investment in new relationships.

> The entire [union grievance handling] committee shows up at meetings to discuss problems, and it's hard to build relationships with them while they are playing their traditional roles in front of each other.

The election of new union officials can sometimes provide an opportunity to try new work practices.

> There was a complete house cleaning of the adversarial union hierarchy in early 1991. The old president was held accountable for shutdowns in the hot end. A few months later, the formal structure of the [employee participation program] began to come into place.

This last interview indicates that the adoption of new work practices was in part facilitated by the change in union leadership, although at this site the impetus for adoption seems to involve both the new union leadership and an earlier shutdown of facilities.

Sources of Production Workers' Resistance in Old Lines

Employees must invest in new relationship-specific skills to work effectively in a new environment of job rotation, teamwork, and pay incentives. At some sites, senior workers opposed new work systems because they opposed the imposition of broader job definitions.

> Senior employees here often have a fear of failing in new jobs. . . . Some also feel physically limited in the jobs they can do.

At other sites, some workers who had advanced to high-paying jobs under a seniority system did not want to let others share in the benefits associated with those jobs:

> Under our old agreement, [no one else] could touch maintenance tools. Workers in these jobs wanted to preserve their territory and the power that comes with being the only one who can do a certain important task.

Long Histories and Labor-Management Mistrust

One common theme echoed in our interviews: a low level of trust between workers and managers in old lines. This mistrust helps explain why labor and management parties with long histories at a given site are less likely to adopt innovative HRM practices than are parties with shorter histories together. The interviews underscore two related points about the importance of trust between labor and management in the adoption of new work practices. First, parties with long tenures are much more likely to have experienced events that damaged trust between labor and management. When there is mistrust, workers will not expend the effort to invest in new skills that have uncertain rewards. Second, mistrust renders ineffective many of the important work practices that comprise the most innovative HRM systems.

On the first point, mistrust between labor and management is fueled by unilateral actions by management, particularly involuntary layoffs, that harm employee welfare. According to one manager:

> There was very little trust in this mill after the employment cuts of 1982.

Layoffs were permitted under all labor contracts of the major U.S. steel producers through the mid-1980s. Involuntary layoffs seem to evoke a sense of injustice that reduces workers' trust about management's commitment to employee welfare.

Managers also indicated that less dramatic involuntary reductions in employee benefits could damage labor-management trust.

> At the end of a slow period, we forced all the workers who had not already scheduled their vacation to take the week off. This was a mistake. It destroyed the cooperative spirit that had been building up. It's taking a long time to rebuild that spirit. It would have been better to shut down the line and have all the workers who didn't want to take their vacation do maintenance work or training.

Finally, some managers acknowledged purposeful violations of existing labor contracts that caused severe breaches in labor-management trust.

> There was a real desperation over our low revenues. We were trying to avoid bankruptcy and needed big cost reductions. [The assignment of maintenance work] violated part of the labor contract.

While subsequent grievance activity adjudicated the issue, the violation of the contract language severely damaged the workers' and the union's trust in management's commitments.

Mistrust and Ineffective HRM Practices

While workers and managers with long histories at a given site often mistrust each other, this pattern alone would not make parties with long tenures at a given site less likely to adopt new HRM practices unless the new work practices require trust to be effective. Our interviews highlighted many cases where attempts to introduce new HRM practices were undermined by low levels of trust between labor and management. For example, with regard to participatory work teams, one manager commented:

> Workers and union leaders thought the Labor-Management Participation Teams [LMPTs] were just another trick by management to cut jobs. Workers called LMPTs ''Less Manhours Per Ton.''

The prior history of layoffs made workers suspicious of how management might respond should employee participation in work teams lead to improved productivity. Even formal contractual guarantees of employment security are not necessarily sufficient to alleviate these suspicions in the presence of mistrust. At another site where management had agreed to a formal contractual guarantee of employment security, workers remembered their plant's experience with layoffs and did not find the employment guarantee credible even though it was specified in the contract.

> Workers out here don't believe they have employment security. They know the contract is going to be renegotiated next spring. Since employment security is only a contractual guarantee, they know it may very well go away in the next contract.

Another individual HRM practice that is part of the most productive system of work practices is information sharing. Mistrusting workers would typically not believe any signs of financial distress suggested by financial reports. According to one manager:

> It's just difficult to change attitudes in old plants with a history of tension and mistrust. We now share financial information with workers, but some workers still believe there are two sets of books.

Birth Effects and the Advantages of New and Reconstituted Lines

In contrast to the experience at lines where workers, managers, and union representatives have long tenures, new lines (as well as old lines reopened by new owners with new workers) are much less likely to have these sources of resistance to innovative HRM practices. However, managers at new sites often discussed the importance of maintaining the trust of the employees. According to a manager at a new line with very progressive HRM practices:

> If I had been a supervisor from [the employees' previous steel mill], the workers would have the whole book on me. They'd know what kind of SOB I was. You can't generate trust starting with those beliefs.

A manager at another site with a progressive set of HRM practices indicated that their facility's approach to these practices

> all boils down to building trust, honesty and confidence.

A trade union official agreed on the importance of "starting over" in order to see productivity improvements from the new HRM practices:

> What you really need to start one of these systems is a bunch of eighteen year-olds. You can form them.

Thus, one competitive advantage of reconstituted lines is that the change in ownership introduces changes in managers and workers that enable the introduction of new work practices. In contrast, older lines must move more slowly, often replacing managers or letting the threat of plant closure pressure workers to adopt new practices.

The Adoption of New Work Practices in Old Lines

During the sample period, old lines rarely made extensive changes to their sets of more traditional work practices. A few, however, did make large-scale changes of this kind. While old lines rarely made extensive changes to their sets of more traditional work practices during the sample period, a small number of old lines did make large-scale changes in many of their work practices. The employee relations manager at one old line felt that the shutdown of much of his mill helped to spur the changes in work practices. This factor alone, he said, would not have been sufficient to produce such change. He felt that several factors came together to create conditions that were right for a broad reform of workplace practices:

> There were three factors that we needed to make the changes here. One was the shutdown. Two was the change in the management and union officials in charge of this place. And three was the [employee participation] program.

Conclusion

This study analyzes the adoption of innovative work practices in a sample of homogeneous manufacturing production units in the steel industry. The distribution of work practices in this sample shows that firms often adopt clusters of complementary work practices—or shows that there are a fairly small number of work practice combinations adopted by the different production units in this industry. Certain combinations of innovative work practices—combinations that emphasize high levels of employee participation in work teams, flexible job design, heavy reliance on incentive pay, and extensive training and communication—produce significant productivity advantages over other combinations of more traditional work practices. These results raise a fundamental question about the adoption of work practices in this narrowly drawn sample: why haven't more of these production units adopted those sets of innovative practices that appear to have such strong effects on productivity?

Our empirical analysis of work practice adoption addresses this question. The analysis yielded two main results. First, the data show evidence of strong "birth effects." In particular, the adoption of the most innovative sets of work practices is confined almost exclusively to the birth of new lines. Older lines do introduce some innovations but only very slowly. These birth effects arise from the birth of the ownership of the line, not from the date the line is physically built. Old lines with old equipment that are shut down and then later reopened with new owners and new employees tend to adopt more innovative work practices than do old continuously operated lines. This suggests that new work practices and new capital are not necessarily complements, but new work practices and new employee relationships are often complements.

Second, there is clear evidence of strong persistence over time in the work practices that older lines use, yet the empirical analysis also shows that credible threats of a line shutdown can motivate these production lines to introduce new work practices. This is especially true when new managers are brought in as part of the process of workplace change.

We interpret both patterns as evidence of the significant costs of changing organizational work practices. These high switching costs reduce the return older lines would otherwise gain from adopting work practices that would improve productivity and revenues. While imperfect information about the effects of work practices on performance may be partly responsible for the limited adoption of innovative work practices, this explanation is not entirely satisfying. In particular, almost every new line adopts extensive sets of innovative work practices, and all changes in the work practices of older lines have been in the direction of switching to more of the innovative work practices. Thus, it appears that managers are increasingly aware of the value of workplace innovations.

Firms must overcome considerable resistance from workers and managers when they want to introduce new work practices. In older lines, workers have made previous investments in relationship-specific skills that are valuable only under the existing set of work rules. New work practices would require workers to bear the costs of investing in a new set of skills. The significant positive impact of the threat of a line shutdown on the adoption of new work practices by older lines suggests that only under dire circumstances, such as the threat of permanent job loss, can the employees' resistance be overcome. Even these conditions are not always sufficient to produce changes in work practices.

Qualitative evidence from interviews with managers and workers at these production sites supports and enriches this interpretation. The interview evidence illustrates that managers, union officials, and workers at older sites often build up vested interests in maintaining their traditional work arrangements. Furthermore, the new work practices appear to require trust between labor and management—trust that is often lacking in long-standing labor-management relationships under traditional work practices. If it is costly to develop trust, this would also help explain the advantage that new lines have in adopting the innovative work practices.

These empirical results can help direct theoretical work on the adoption of work practices. The empirical patterns support recent findings that complementarities among work practices can be important. Our results highlight, however, the importance of sizable switching costs in firms' adoption decisions—costs that are not currently considered in existing models of complementarity among work practices.

Even more broadly, the results on the adoption of work practices identify an interesting similarity between labor and capital. A firm that wishes to introduce technological changes in capital will generally find it less expensive to build a new plant than to retool an existing one, which requires substantial sunk costs.[41] A firm that wishes to introduce innovations in the management of its labor resources may also find it less expensive to open a new plant with new managers and workers. In both cases the characteristics of the capital stock and labor resources are embodied in the old technology. Thus, when firms invest in the relationship-specific human capital of their workers, the firm is limiting its future ability to make changes in workplace organization.

41. See Salter (1969) for a discussion of technological change.

Comments and Discussion

Comment by Robert W. Crandall: Several years ago I visited the headquarters of the most successful steel company in North America—a minimill. After hearing from its CEO its rather uncomplicated secret to its success—cooperative industrial relations practices and extremely prudent investment outlays on new scrap-based plants—I asked the CEO why the large, integrated firms would not quickly emulate his and eliminate any potential gains from this simple strategy. He just smiled. He and I both knew that the heritage of Big Steel's labor relations, its existing labor contracts, and a long history of overengineering everything from executive hunting lodges to continuous casters made them permanently noncompetitive.

In this paper Ichniowski and Shaw provide us with an elegant empirical methodology that allows them to reach much the same conclusion: workers with long tenures in old, unionized steel plants are thoroughly resistant to change in labor practices. Workers in "reconstituted" plants are, however, more likely to accept these changes. And workers in "new" facilities are most likely to change.

Missing from this analysis, however, are details about the nature of the union agreements for the period of their analysis, which by themselves could explain the authors' findings. In addition, I fear that the analysis focuses on but one small part of the productivity puzzle: the proportion of the time that a production line is actually running. There is more to productivity than "uptime." Otherwise, minimills could not possibly enjoy the enormous productivity advantages (roughly 3 to 1) over the integrated firms that has allowed them to drive the larger firms from virtually every product line that they have entered in the past twenty years.[1]

The Production Process

The authors study the behavior of thirty-five "finishing lines" in the steel industry during the 1991–93 period, collecting confidential data for an undefined period that spans the 1980s and 1990s. Although they cannot tell us, it is a safe bet that the "finishing line" is a cold-rolling mill that converts hot-rolled sheet into cold-rolled sheet for automotive and appliance applications as well as for further coating. Cold-rolling facilities are incredibly diverse, ranging from simple reversing mills to enormous continuous cold-rolling and annealing facilities. The former are found in large and small firms alike; the latter are found only in large U.S. firms, often built and operated with an Asian partner. The quality and productivity of these facilities vary enormously, as does their output, because of differences in the width and gauge of products rolled.

The Hypothesis

The authors offer the hypothesis that the probability of adopting modern human resource management (HRM) practices that induce workers into a more cooperative, productive mode of behavior is affected by the benefits of such practices to the firm and the cost of inducing workers to make the necessary adjustment, including the human capital investment required. The benefits depend on the expected revenues from adopting HRM, specifically, the improvement in output and product quality. The costs of inducing workers to mend their ways is expected to rise with job tenure of both workers and managers but to decline with the probability of plant closure.

The Productivity Benefits

The benefits measured by the authors, however, are only part of the benefits of changing labor attitudes and practices. Ichniowski and Shaw

1. The jury is still out on commodity-grade sheet products, but, if the minimills solve their metallics input problems (scrap is being exhausted by their expansion), I would predict that most integrated producers will be driven from this market as well.

measure "productivity" by the proportion of time a line is operating, assuming implicitly that labor and capital are used in fixed proportions when the line is in operation. But there are large differences in the amount of labor used to operate and *maintain* these facilities. I would hazard a guess that the authors were unable to obtain reliable estimates of the direct and indirect labor used in these facilities. Alternatively, it may be that such data were simply unreliable. Therefore, the authors used a proxy for productivity—the proportion of *scheduled* hours that the mill actually operated.

Unfortunately, the proportion of scheduled time that a mill operates is only one determinant of productivity. Manning practices, scheduling, the variance in product widths, and a variety of other operating practices are likely to be more important. In addition, the measure used by the authors results in mean downtime (from schedule) of only 8 percent, whereas total downtime for a cold-rolling mill is more likely to be in the 20 percent range. One cannot be sure how "scheduled" time is actually calculated or the extent to which measurement error is correlated with the regressors in the productivity equation.

Thus the authors do not measure the impact of changing labor relations on labor productivity. Instead, they measure the impact on one of the determinants of productivity. Their results show that the most innovative labor-management practices increase operating time by 6 to 7 percent, a remarkably small effect given the productivity-enhancing potential of changing manning practices, scheduling, and other operating parameters. For example, I know of one cold-rolling mill in a company, which recently changed management, that increased its output by more than 60 percent in less than two years. Given the considerable inefficiency of many operations in the 1980s, a 6 or 7 percent improvement in output is almost inconsequential.

"Adoption" Rates

Although the authors have not captured the full effects of innovative labor relations on productivity, no one can seriously doubt that such effects exist and are likely to be large. The interesting question thus becomes: Why have such labor relations practices not been adopted by even the laggards in the industry? Only 8 percent of the authors' "older" lines adopt their most innovative practices, denoted HRM1 and HRM2. The rest of the dinosaurs are mired in HRM3 and HRM4, the antediluvian labor-relations modes.

The authors use a multinomial logit model to estimate the determinants of adopting each of the modern labor relations modes. Their hypothesis is that worker and manager tenure are inversely related to the probability of adopting the more innovative approaches. Unfortunately, they were not provided with worker tenure data, for reasons that will be apparent below. Thus their results depend on the assumption that *LINETEN*, the number of years that the line has been owned by the current management, is a good proxy for worker tenure. This is not an unreasonable assumption. A linear model that uses a weighted index of the twenty-six different labor-management practices that are used to construct HRM1 through HRM4 provides the same general results: labor and management tenure is bad for innovation.

The authors use a variety of technology "controls" in both their productivity and adoption equations that they do not fully explain, presumably because of the confidentiality of the data. These controls could be crucial in explaining their productivity measures and could conceivably lead to biased estimates of the various HRM measures. In addition, the authors include variables for the percentage of the product sold in a national market (*NATIONAL*), and the number of "new" competitors is in the eye of the beholder. In fact, there is a great deal of substitutability at the margin across all cold-rolling mills. Even the newest, most sophisticated mills produce a great deal of "secondary" material that is channeled to the commodity-grade market. Wide mills can roll narrow products. Gauges can be adjusted.

The Role of Union Agreements

There is an alternative explanation for the authors' "adoption" results that is rooted in the union agreements signed by managements in triennial negotiations in the late 1970s and early 1980s. These agreements provided for ever more attractive fringe benefit packages plus protection against plant closures. Specifically, workers were provided with early retirement benefits in the event of a plant closure. Workers whose age and job tenure added to 65 were given $400 a month plus accrued retirement benefits and health benefits in the event of a plant closure; those whose age and tenure added to 70 or 80, depending on their age, were provided the $400 a month plus retirement without diminution of benefits even if they took another job.

Once a substantial share of workers become eligible for these early retirement benefits, they would not be very receptive to new ideas rendered by management for working more diligently or efficiently. Moreover, because the present value of these added early retirement benefits could easily amount to $100,000 to $200,000 a worker—a sum that would have to be accounted for in the company's balance sheet when a closure is announced—a plant shutdown could easily bankrupt any company except U.S. Steel once a significant number of workers became eligible for these benefits. The result was that many plants were undoubtedly kept in operation at inefficient output levels so that the firm could avoid taking these shutdown charges. In this atmosphere, there may be *no* benefits to improvements in the number of hours that a finishing mill operates because increased output would have to be compensated by reductions in output and plant closures elsewhere.

When plants finally did close, their owners were generally forced into bankruptcy. Republican, Jones and Laughlin, Youngstown Sheet & Tube (all since consolidated into LTV Steel), Wheeling-Pittsburgh, Charon, CF&I, and Kaiser Steel closed facilities and entered Chapter 11 proceedings. Most reopened with fewer facilities as the "reconstituted" mills, to use the authors' parlance. Besides shedding their debts and some of their retirement obligations (through the Pension Benefit Guaranty Corporation), these reconstitutions generally included a new labor agreement that allowed more flexibility in manning practices and more of HRM1 through HRM3 of the authors' classification.

If I am correct, these early retirement packages provide a potent explanation for why older plants were so lacking in "innovative" labor-management practices. Managements could not afford to shed their workers, and workers knew this. The effect on productivity must have been devastating. This surmise is not at variance with the authors' results; it simply makes them appear somewhat obvious. The interesting question is why managements signed such agreements. Perhaps Ichniowski and Shaw could investigate this question in a subsequent paper. Their interviews for this project would surely be conducted in much more pleasant locations, such as south Florida or Arizona, to which the signatories have long since repaired.

General Discussion: Several participants commented on the apparently slow diffusion of productivity-enhancing human resource management (HRM) practices. Noting that the authors had shown that very substantial economic gains are associated with new practices that raise production line uptime, Robert McGuckin argued that the slowness in adopting such practices might be connected to the concerns of older workers fearful of salary reductions and layoffs. According to Bronwyn Hall, a period of productivity decline is likely to occur when new HRM practices are forced upon older workers, causing firms to be reluctant to introduce them to veteran labor forces. She suggested that the authors try to separate the purely economic determinants of the diffusion of new practices from those associated with the resistance of workers and managers to change.

F. M. Scherer presented anecdotal evidence to support the authors' contention that managerial legacy is an important factor affecting the adoption of new HRM practices. He said that in 1973 he visited the world's two newest 84-inch cold-strip steel mills—one in Japan, the other in Illinois. According to Scherer, both plants had new work forces and operated with the same cutting-edge technology, but the Japanese mill appeared to be far more productive. The key difference between the plants, he surmised, was management. The Japanese managers urged their workers to devise new ways to operate the mill more efficiently while minimizing waste. The operating team worked in unison, like a ballet company. The U.S. plant, in contrast, was dirty and littered with defective coils, a likely sign of lax management. Feeding new coils into the mill was plainly less well-coordinated and slower than it was in Japan.

Ariel Pakes said that monetary sunk costs must influence a firm's decision to adopt new HRM practices. He argued that the importance of such costs depends upon the growth rate of the firm, especially if there is some probability that it will go under. According to Pakes, this issue should be of particular concern to the authors, because the steel industry has witnessed several declining and failing firms.

Pointing out that most cross-sectional industry studies have found huge variations in plant productivity, even when the same technology is used within the same firm, Timothy Bresnahan contended that competition may not be a very effective mechanism for creating incentives to adopt productivity-enhancing practices. As a result, he said, incremental changes in HRM practices on existing production lines may be relatively rare. Instead, he argued, the paper appeared to show that new HRM practices are generally adopted in toto when an old line is reconstituted or a new one is started up—in other words, on those occasions when a clear picture emerges of the costs and benefits associated with these new practices.

Several participants also discussed data, measurement, and modeling issues. Frank Wolak argued that the authors' use of production line uptime as a measure of total factor productivity differed from the traditional definition of this concept as the ratio of output produced to aggregate inputs used. He noted that two production lines with the same total factor productivity could have different uptimes; the production line with the lower uptime would use fewer inputs and thus produce less output. Wolak also pointed out that the large estimated first-order serial correlation coefficients associated with the errors to the regressions strongly suggest that the adoption of new HRM practices is a dynamic process. He recommended that the authors run additional regressions including lags of the dependent and independent variables to capture these dynamics, rather than assume autocorrelated errors in a static regression model.

Pakes argued that the authors' data should allow them to reconstruct their model to test for the adoption of each of the twelve HRM innovations they identified and, consequently, to see if there is genuine complementarity among them. He also said that the set of decisions regarding which HRM practices to adopt for new production lines differs from those of existing lines; as a result, a separate analysis for new lines might be warranted.

Noting that the output of steel mills is not as homogeneous as, for example, that of electricity generating plants, Michelle White argued that the authors should account for product differentiation. Some products, she said, are likely to be more profitable than others on the basis of capital per worker or per unit. In addition, she contended, it is possible that certain types of output are naturally associated with less production downtime than others. Agreeing with White's comments, Peter Pashigian said that it might actually be optimal for some firms to produce goods of lower quality than those of their competitors. Buyers, he argued, will be aware that they are receiving lower quality items, which, in turn, should be reflected in lower prices. He noted that this phenomenon occurs in the auto industry, where customers pay less for American cars than for Japanese ones because of assumed quality differences.

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