Do U.S. Firms Invest Less in Human Resources? Training in the World Auto Industry

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We investigate the common assertion that U.S. firms invest less in human resources than key international competitors, testing four alternative explanations for differences in training effort found in survey data from an international sample of fifty-seven automobile assembly plants. We find the strongest support for the view that the level of training is derived from the requirements of the business/production strategy and the overall "bundle" of human resource policies—beyond training—adopted by the firm.

IN THIS PAPER, we investigate the often asserted but untested argument that U.S. firms invest less in human resource development of workers relative to their key international competitors (Dertouzos, Solow, and Lester, 1989). We do so by testing four alternative explanations for differences in cross-firm and cross-national training investments observed in an international sample of fifty-seven automobile assembly plants: (1) national-level comparative advantage with respect to human resources; (2) national-level cultural and/or institutional proclivities; (3) new or advanced technologies that require training for new skills; and (4) firm-level strategic choices about how to organize technical and human capabilities within the overall production system.

The macrolevel competitiveness debates have done a good job of stating the basic comparative advantage proposition. Training is important to firms in the United States and other advanced economies because they

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cannot compete successfully with low-wage countries on labor costs. Therefore, they must seek comparative advantage from product quality, flexibility, innovation, and product differentiation (Piore and Sabel, 1984), which requires a high-quality labor force. The first hypothesis, therefore, is that firms in advanced industrial economies such as the United States, Japan, and the countries of Western Europe would be expected to train more than firms in low-wage, newly industrialized countries. Since the required skills are often firm-specific, this hypothesis would hold even if one assumes that a higher base of skills is provided by the educational system in these countries than in the low-wage countries.[1]

But among advanced economies, why do we believe there is variation, and particularly variation that reveals low levels of training for U.S. firms? The second hypothesis focuses on macrolevel differences either in national culture or in the industrial relations system that emerge from a country's history and institutional context. Japan, for example, is argued to invest more because "lifetime employment" policies for core employees make labor a fixed rather than a variable cost, thus increasing the value of investments in firm-specific skills (Koike, 1988; Shimada, 1983). Germany is said to invest more because of a national industrial and educational policy that provides apprenticeship training during the secondary school years to facilitate the school-to-work transition (Casey, 1986; Wever, Kochan, and Berg, 1992).

The third hypothesis operates at the industrial or firm level, and takes a "technological upgrading" view—that the implementation of advanced technology will require more highly skilled "knowledge workers" who will need high levels of training (Adler, 1986). The opposite hypothesis—that technological change leads to a net *reduction* in skills and hence a reduced need for training—has also been advanced, as part of the "upskilling vs. downskilling" debate. Empirical evidence to date is inconclusive; automation results in some upskilling and some downskilling, across occupations and different industry contexts (Cappelli, 1993; Attewell, 1992; Kelley, 1989). These findings have stimulated various contingency versions of the "upgrading" hypothesis that emphasize the firm's strategic choices about how technology is used.

[1] From this perspective, one should expect the educational system of the advanced industrialized countries to produce graduates with a high level of basic skills that can be further developed through firm training. Given the current furor about the problems of the U.S. educational system, it is clear that this hypothesis does not always hold. Nevertheless, this hypothesis would anticipate an even higher level of training in order to compensate for any deficits in the educational system. This leaves unresolved the claim by some U.S. companies that the poor educational system prevents them from finding the skilled employees necessary for the high value-added strategy.

The fourth hypothesis operates at the level of the firm and suggests that training investments are dependent on firm-level strategic choices rather than exogenous factors such as macroeconomic context, national culture, or new technologies. This hypothesis draws on what strategy researchers call the "resource-based view of the firm" (Barney, 1986) for its view that business and production strategies emerge from a firm's "core capabilities"—the knowledge of products and processes and relationships with suppliers and customers that convey sustainable competitive advantage. These capabilities are grounded in the firm-specific skills of employees, which provides an incentive for both on-the-job and off-the-job training (Cappelli and Singh, 1993).

This hypothesis also draws on two themes found in recent literature on the link between human resource (HR) practices and economic performance: (1) that "bundles" of interdependent HR practices, rather than individual practices, are the appropriate level of analysis for understanding the link to performance (Ichniowski, Shaw, and Prennushi, 1993; Arthur, 1992; Cutcher-Gershenfeld, 1991; MacDuffie, 1995); and (2) that these HR bundles or systems must be integrated with the firm's business strategy to be effective (Majchrzak, 1988; Kochan, Cutcher-Gershenfeld, and MacDuffie, 1991).

From this perspective, the level of training is derived from the requirements of the overall business strategy and the bundle of HR policies—beyond training—adopted by the firm. In the context of the automotive industry, we argue that firms using flexible production systems require more skill and motivation from employees than those using traditional mass production. As such, they have a strong incentive to invest in a bundle of innovative HR practices—including a high level of training—that yield the desired work force capabilities, irrespective of national context or level of technology. We develop this hypothesis further below, in the context of flexible production.[2]

In the studies cited above, training is treated as one item in the bundle of HR policies and the whole bundle is used as the relevant dependent or independent variable. Here we need to separate out training from the

[2] These hypotheses do not address the issue of how training affects economic performance. Another paper based on these data (MacDuffie, 1995) finds that flexible production plants, which combine low levels of buffers with bundles of HR policies promoting worker motivation and skill development, achieve higher productivity and quality than traditional mass production plants. The role of training in performance is subsumed under the broader question of how the overall HR system affects performance. This is consistent with the "flexible production systems" hypothesis, and suggests a related (although untested) hypothesis—that high training levels alone, in the context of a traditional mass production system, would not lead to better economic performance.

overall bundle to test the influence of firm choices about production system and HR policies relative to the larger forces captured by the national-level and technology hypotheses. Support for the fourth hypothesis will indicate that flexible production systems do have high levels of training, as the "bundling" perspective implies. However, some plants with mass production systems may very well train at high levels because of the national industrial relations system or the level of advanced technology.

Sorting out the relative importance of these explanations should have implications for public policy. If the comparative advantage explanation dominates, then natural market forces should lead firms operating in advanced industrial countries to invest in training since it will be the only way to sustain their high-skill advantage. If the national culture/institutions hypothesis dominates, then public policy needs to focus on national strategies and structures for requiring or encouraging firms and workers to invest in training. If technology drives training, then strategies that encourage investments in automation should suffice. If transforming production and human resource systems increases training, then policies that encourage these organizational transformations are called for.

The "Organizational Logic" of Flexible Production

Flexible production organizes both technical capabilities and human capabilities differently than mass production, with direct implications for training. The "organizational logic" of flexible production *reduces* the technical system's ability to function in the face of contingencies (problem conditions) through the minimization of buffers of all kinds—thus reducing slack, increasing task interdependence, and raising the visibility of problems—and *expands* human capabilities, so that people can deal effectively with these problem conditions and achieve improvements in the production system.

Under mass production, the realization of economies of scale is paramount, so buffers (e.g., extra inventories or repair space) are added to the production system to protect against potential disruptions, such as sales fluctuations, supply interruptions, and equipment breakdowns. Such buffers are seen as costly under flexible production because they hide production problems. As long as inventory stocks are high, a defective part has no impact on production, because it can simply be scrapped and replaced. But when inventories are very low, as with a Just-in-Time inventory system, a bad part can bring the production system to a halt. The minimization of buffers serves a cybernetic or feedback function, providing valuable information about production problems (Schonberger, 1982).

Under flexible production's philosophy of continuous improvement, problems identified through the minimization of buffers are seen as opportunities for organizational learning (Ono, 1988; Imai, 1986). Ongoing problem-solving processes on the shop floor, alternating between experimentation with procedural change and the careful standardization of each improved method, yield a steady stream of incremental improvements (Tyre and Orlikowski, 1993). In a sense, the "buffering" capability to cope with change shifts from the technical system to the human system (Adler, 1992; Cole, 1992; MacDuffie, 1991).

In order to identify and resolve quality problems as they appear, workers must have both a conceptual grasp of the production process and the analytical skills to identify the root cause of problems.[3] To develop such skills and knowledge, flexible production utilizes a variety of multiskilling practices, including work teams, quality circles, job rotation within a few broad job classifications, and the decentralization of quality responsibilities from specialized inspectors to production workers. Furthermore, to insure that workers contribute the attentiveness and analytical perspective necessary for effective problem-solving, flexible production is characterized by such "high commitment" human resource policies as employment security, compensation that is partially contingent on performance, and a reduction of status barriers between managers and workers (Shimada and MacDuffie, 1986).

This account of flexible production is challenged by various observers (e.g., Parker and Slaughter, 1988; Huxley, Robertson, and Rinehart, 1991) who claim that such a system is based on "management by stress." The reduction of buffers is said to increase work pace and to create stress among workers by focusing blame on them when mistakes are found. Related changes in work organization (e.g., teams) and human resource

[3] For example, there are many possible reasons why a worker might have difficulty installing a component on the assembly line. The component could have quality problems as delivered by the supplier that must be fixed before it can be installed. The attachment holes on the body may not be drilled or may be in the wrong location due to problems in the welding department, or blocked with sealer because of improper application in the paint department. A misinstalled part from an upstream operation on the assembly line could be the problem. A tool with the wrong torque could strip the threads on a bolt during the fastening process. The immediate decision for a worker is whether or not to stop the assembly line, in order to remedy the situation quickly (e.g., scraping off the sealer blocking an attachment hole). The next step is to find out whether the problem is recurrent and, if so, to develop a short-term "countermeasure" to prevent defects from continuing to be produced. The team leader and support staff would help here by communicating information about the defect to the supplier or the appropriate upstream department or work station. Finally, in a "off-line" quality circle or other form of problem-solving group, workers would seek a "permanent" countermeasure, applying various analytical techniques (e.g., Statistical Process Control, Pareto analysis, "fishbone" analysis, using the "five whys" to track each problem back to its "root cause").

policies (e.g., performance-linked pay) are seen as efforts to increase management influence and weaken worker solidarity. High levels of training under flexible production are similarly seen as efforts to exert cultural control over workers, socializing them to accept the demands of the production system, rather than to impart necessary skills. While the data available for this paper do not allow these issues to be addressed directly, this view of flexible production will be considered in the closing discussion.

Training under Flexible Production

Unlike mass production, which is premised on the assumption that production work involves little skill and requires little training, flexible production sees production workers as skilled problem solvers who must be adequately prepared for their task through effective training. One consequence is that flexible production requires a high level of competency in reading, math, reasoning, and communication skills. If the existence of these skills is not reliably guaranteed by the public educational system, flexible production plants are likely to screen carefully for these skills or to provide remedial training.

Under flexible production, the majority of training in technical skills is carried out by the firm, through a lengthy period of on-the-job training (OJT) (Koike, 1988). In contrast, mass production firms tend to provide limited off-the-job technical training in classroom settings, which they view as superior to OJT. Under mass production, OJT has had a connotation of brief, informal training—for example, a new hire who is given a few hours of instruction from a co-worker and then "learns the ropes" through unstructured observation and imitation. By comparison, OJT in flexible production plants involves trainers who work intensively with new hires, at first demonstrating, then coaching, and who stay on the shop floor after initial training to show workers how to handle non-routine problem conditions (Ford, 1986). This is a very effective way to convey tacit knowledge about jobs and leads to high retention of what is learned, both because of its experiential approach and because individuals acquire skills very close to the time when they will need to use them.

Finally, training in these flexible production plants aims to teach not only substantive knowledge but also processes of problem-solving and learning (Imai, 1986; Lillrank and Kano, 1989). This training, combined with employment continuity policies, reinforces the willingness of the firm to invest heavily in its employees, thus bolstering the cultural norms of reciprocal obligation that help maintain employee commitment and motivation under flexible production (Dore, 1992).

Thus, having a work force that is multiskilled, adaptable to rapidly changing circumstances, and with broad conceptual knowledge about the production system is critical to the operation of a flexible production system. The learning process that generates these human capabilities is an integral part of how the production system functions, not a separate training activity. The demand for training is a function of the extent to which a flexible production system is deployed (Sako, 1992).

Hypotheses

The four competing hypotheses on training we are testing can be summarized as follows:

H1: Comparative advantage. Investments in training result from national comparative advantage with respect to human resources. Specifically, firms in the advanced industrial economies (U.S., Japan, and Western Europe) that cannot compete on the basis of low labor costs will invest more in training than "low wage" newly industrialized countries.

H2: National institutions. Investments in training result from the education/training institutional infrastructure that exists in different countries for cultural and/or historical reasons. Specifically, firms located in Japan and Germany (among other European countries) will invest more in training than firms located in the U.S. and newly industrialized countries.

H3: Technology. Investments in training result from the extent to which the firm has implemented advanced automation. Specifically, firms with higher levels of robotics will invest more in training than firms with fewer or no robots.

H4: Flexible production. Investments in training are an interrelated part of the firm's choices about business/production strategy and the overall human resource system. Specifically, firms that utilize a flexible production system will invest more in training than firms utilizing a mass production system.

Empirical Evidence

Sample. Our data are from the International Assembly Plant Study, carried out through the International Motor Vehicle Program (IMVP) at M.I.T.[4] Ninety assembly plants were contacted, representing twenty-four

[4] The International Motor Vehicle Program (IMVP) was a five-year research program (1985–90) sponsored by virtually every automotive company in the world (Womack, Jones, and Roos, 1990). IMVP continues now as one of the Sloan Foundation-funded centers for the study of industrial competitiveness.

producers in sixteen countries, and approximately 60 percent of total assembly plant capacity worldwide. Survey responses were received from seventy plants during 1989 and early 1990. The proportion of plants in different regions is closely related to the proportion of worldwide production volume, with some underrepresentation of Japanese plants in Japan and overrepresentation of Newly Industrialized Countries (NIC) and Australian plants, whose volumes are low. Plants were chosen to achieve a balanced distribution across regions and companies, and to reflect a range of performance within each participating company, minimizing the potential for selectivity bias.

Questionnaire Administration. Questionnaires were sent to a contact person who distributed different sections to the appropriate departmental manager or staff group. Plants and companies were guaranteed complete confidentiality and, in return for their participation, received a feedback report comparing their responses with mean scores for different regions. All ninety plants that were contacted were visited by one of the two primary researchers between 1987 and 1990. Early visits provided the field observations that became the foundation of the assembly plant questionnaire. For the seventy plants that returned a questionnaire, the visit often followed receipt of the questionnaire, providing an opportunity to fill in missing data, clarify responses that were unclear or not internally consistent, and carry out interviews to aid the later interpretation of data analyses.

Variables. Methodological details for variables in the Assembly Plant Study, including the control variables used here, can be found in Krafcik (1988), MacDuffie (1991), and MacDuffie and Krafcik (1992). Here only the main dependent and independent variables are described in detail. For these variables, we have complete data from fifty-seven plants.

In comparison with other studies, the data used here have a number of advantages, particularly in the measurement of HR practices. Many studies of HR practices look across industries and must therefore specify those practices in broad, general terms. Furthermore, many such studies measure practices at the firm level, with little indication of within-company variation (e.g., Ichniowski, 1991; Lawler, Mohrman, and Ledford, 1992). In comparison, these data come from one context, thus controlling for industry and technology/task complexity. Questions are customized to auto assembly plants, boosting their reliability and allowing intracompany variation to be captured.

Training Effort. This dependent variable is based on the number of hours of off-the-job and on-the-job training received by new and experienced (over one year of employment) production workers.[5] They are the employees most likely to receive different training treatment in the situations captured by the four hypotheses—particularly in auto assembly, where production work has traditionally been seen as unskilled (or marginally semi-skilled) work requiring little training.[6] Since new hires typically receive many more hours of training than experienced production workers do annually,[7] training hours for these two groups are standardized by conversion to z-scores before being added together to form the Training Effort measure. To aid interpretability when presenting regional means, the summed z-scores are rescaled so that 0 represents the plant with the lowest training effort in the sample, and 100 the plant with the highest effort. Table 1 contains regional means for actual training hours for these two groups of employees, as well as means and standard deviations for the Training Effort index and t-tests for statistically significant differences in the regional scores.

One caveat with an effort-based measure of training is that more training is not always better than less training. The Training Effort measure does not distinguish between different topics or different methods of training. As such, it cannot address questions about what kinds of training in what areas are most effective.

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[5] The questions on training asked for hours of training per employee provided in the first six months of employment (for new hires) or in the past calendar year (for employees with more than one year of previous experience) for three groups of employees: production workers, first-line supervisors, and plant engineers. These total hours are divided between the percentage provided on-the-job and the percentage provided off-the-job. Other training questions asked about whether off-the-job training was provided by plant staff, corporate staff, outside consultants/educational institutions, or vendors. Open-ended questions asking for the "five most important training topics" proved difficult to evaluate because of the wide diversity of topics that were listed and the difficulty in interpreting the content of topics in an international sample.

[6] Training hours for maintenance/skilled trades workers were not measured. This raises the question of whether the training of production workers allows them to do tasks once performed by skilled maintenance workers, with a consequent reduction in training for this latter group. While there is evidence that the *number* of indirect employees (who perform maintenance, material handling, and quality control tasks) is lower in flexible production plants (Ittner and MacDuffie, 1994), there is little reason to expect that the *skill level* of maintenance workers (and hence their need for training) in flexible production plants would be lower because of higher levels of training for production workers. Presumably well-trained production workers would take over simple maintenance tasks requiring relatively little technical skill, thus boosting the skill content of tasks performed by maintenance workers.

[7] One might expect the level of training to vary as a function of the educational level of employees, both new hires and experienced workers, and in relation to whether the plant is new and hiring lots of employees or old and hiring few (or no) employees. Both of these factors were investigated as variables added to the regression analyses reported below, but neither helped explain any of the variation in training.

TABLE 1

REGIONAL MEANS
TRAINING HOURS AND TRAINING EFFORT INDEX FOR PRODUCTION WORKERS

	Jpn/Jpn	Jpn/NA	US/NA	US/Eur	Eur/Eur	NIC	Aust
Newly Hired Production Workers (hours in first 6 months)	364	225	42	43	178	260	40
Experienced Production Workers (hours per year for those with over 1 year of experience)	76	52	31	34	52	46	15
Training Effort Index[a]	49.1[b]	31.5[c]	12.5[d]	13.6[e]	28.5[f]	31.0[g]	6.0[h]
S.D. for Training Effort Index	28.6	8.2	8.0	12.7	20.8	31.8	3.9
n	8	4	14	4	10	11	6

[a] Index is the sum of z-scores for training hours for new and experienced production workers, rescaled from 0 to 100. Significance level for all t-tests is $p < .05$.
[b] Mean significantly different from US/NA, US/Eur, Aust.
[c] Mean significantly different from US/NA, US/Eur, Aust.
[d] Mean significantly different from Jpn/Jpn, Jpn/NA, Eur/Eur, NIC.
[e] Mean significantly different from Jpn/Jpn, Jpn/NA.
[f] Mean significantly different from US/NA, Aust.
[g] Mean significantly different from US/NA, Aust.
[h] Mean significantly different from Jpn/Jpn, Jpn/NA, Eur/Eur, NIC.

Jpn/Jpn = Japanese-owned plants in Japan
Jpn/NA = Japanese-owned plants in North America
US/NA = U.S.-owned plants in North America
US/Eur = U.S.-owned plants in Europe
Eur/Eur = European-owned plants in Europe
NIC = Newly industrialized countries (Korea, Mexico, Taiwan, Brazil)
Aust = Australia

Production Organization Measures. To operationalize the "organizational logic" of flexible and mass production systems, two measures related to a plant's production organization are developed: Use of Buffers and HR System. Each is an index made up of multiple variables, described below, that are standardized by conversion to z-scores before being additively combined. Each index is then transformed for easier interpretability, on a scale from 0 to 100 where 0 is the plant with the lowest score in the sample and 100 the plant with the highest score. Reliability tests for each index show a Cronbach's alpha score of .63 for Use of Buffers and .80 for HR System. Table 2 contains the means of individual variables making up these two indices and the indices themselves, for the whole sample and for three clusters of plants—mass production and flexible production plants at the ends of the continuum and a group of "transition" plants in between.[8]

[8] Previous analyses comparing various clustering methods (not reported here) found that the Euclidean measure for distance between cluster centroids and the Within Group Average method of forming clusters produced the most statistically distinct clusters. These methods were used to derive two, three, and four cluster solutions. Means from the three-cluster solution are presented here, since they can be readily interpreted.

TABLE 2

MEANS OF PRODUCTION ORGANIZATION VARIABLES AND INDICES ACROSS CLUSTERS OF PLANTS

Variable	Sample (n = 57)	MassProd (n = 29)	Transition (n = 14)	FlexProd (n = 14)	F
Repair Area (Sq. feet as % Assembly Area)	10.4	13.7	9.1	4.8	15.8***
Paint-Ass'y Buffer (% of 1-shift production)	23.3	29.7	18.7	14.6	3.9**
Inventory Level (Days supply for 8 parts)	2.1	2.8	2.1	0.63	18.7***
% Work Force in Teams	22.4	5.0	10.4	70.2	38.6***
% Work Force in El, QC Groups	32.5	16.5	20.9	77.4	17.8***
Suggestions per Employee	9.2	0.24	0.33	36.5	15.3***
% Suggestions Implemented	36.3	25.5	23.8	72.0	16.8***
Job Rotation Index (0 = none, 4 = extensive)	1.8	1.2	1.9	3.0	20.8***
Quality Control at Shop Floor (0 = none, 4 = extensive)	3.1	2.6	2.9	4.5	2.8*
Hiring Criteria (Low = match past experience to job, High = interpersonal skills, willingness to learn new skills)	35.1	32.7	35.8	39.4	12.7***
Training New Hires (0 = low, 3 = high)	1.6	1.0	1.9	2.4	13.1***
Training Experienced Employees (0 = low, 3 = high)	1.4	0.9	1.6	2.1	7.9***
Contingent Compensation (0 = none, 4 = based on plant performance)	1.6	0.72	2.2	3.0	20.0***
Status Differentiation (0 = extensive, 4 = little)	1.9	1.1	2.0	3.4	17.7***
Use of Buffers Index	58.7	44.7	62.7	83.5	28.3***
Human Resource System Index	33.6	16.1	30.1	73.2	59.4***

* Statistically significant at .10 level; ** statistically significant at .05 level; *** statistically significant at .01 level.

Use of Buffers: This index measures a set of production practices that are indicative of overall production philosophy with respect to buffers (e.g., incoming and work-in-process inventory), with a low score signifying a "buffered" system and a high score signifying a "lean" system. It consists of three items:

- the space (in square feet) dedicated to final assembly repair, as a percentage of total assembly area square footage;
- the average number of vehicles held in the work-in-process buffer between the paint and assembly areas, as a percentage of one shift production; and
- the average level of inventory stocks, in days for a sample of eight key parts, weighted by the cost of each part.

HR System: This index captures how work is organized, in terms of both formal work structures and the allocation of work responsibilities, the participation of employees in production-related problem-solving activity, and HR policies that affect the "psychological contract" between the employee and the organization, and hence employee motivation and commitment. A low score for this index indicates an HR system that is "low-skill" and "low-commitment" in orientation, while a high score indicates a "multiskilling," "high-commitment" orientation. It consists of seven different items:

- the percentage of the work force involved in "on-line" work teams and "off-line" employee involvement groups;
- the number of production-related suggestions received per employee and the percentage implemented;
- the extent of job rotation within and across teams (0 = no job rotation, 1 = infrequent rotation within teams, 2 = frequent rotation within teams, 3 = frequent rotation within teams and across teams of the same department, 4 = frequent rotation within teams, across teams and across departments);
- the degree to which production workers carry out quality tasks (0 = functional specialists responsible for all quality responsibilities; 1, 2, 3, 4 = production workers responsible for 1, 2, 3 or 4 of the following tasks: inspection of incoming parts, work-in-process, finished products, gathering Statistical Process Control data);
- the hiring criteria used to select employees in three categories: production workers, first line supervisors, and engineers (the sum of rankings of the importance of various hiring criteria for these three groups of employees, with low scores for criteria that emphasize the fit between an applicant's existing skills and job requirements ("previous experience in a similar job") and high scores for criteria that emphasize openness to learning and interpersonal skills ("a willingness to learn new skills" and "ability to work with others");
- the extent to which a compensation system is contingent upon performance (0 = no contingent compensation; 1 = compensation contingent on corporate performance; 2 = compensation contingent on plant performance, for managers only; 3 = compensation contingent on plant performance or skills acquired, production employees only; and 4 = compensation contingent on plant performance, all employees);
- the extent to which status barriers between managers and workers are present (0 = no implementation of policies that break down status barriers and 1, 2, 3, 4 = implementation of 1, 2, 3, or 4 of

these policies: common uniform, common cafeteria, common parking, no ties).

Robotic Index. This variable indicates the extent to which advanced technology is used in a plant. It measures the number of robots, defined as programmable equipment with at least three axes of movement, in the weld, paint, and assembly departments of an assembly plant, adjusted for plant scale. This is one of two alternate technology variables used in the larger study. The other, Total Automation, covers the entire automation stock of a plant, measuring the percentage of direct production steps in the welding, paint, and assembly areas that are automated. While Total Automation is more comprehensive, it does not distinguish the age or type (e.g., programmable vs. dedicated) of automation. Thus the Robotic Index is more appropriate for testing the technology hypothesis, given that training needs are said to increase most when new, programmable technology is implemented.[9]

Control Variables. Four other measures of the plant's production system are used here as controls. **Plant Scale** is defined as the average number of vehicles built during a standard, non-overtime day, adjusted for capacity utilization. **Model Mix Complexity** measures the mix of different products and product variants produced in the plant. It includes the number of distinct platforms, models, body styles, drive train configurations (front-wheel vs. rear-wheel drive), and export variations (right-hand vs. left-hand steering). The **Parts Complexity** index includes three measures of parts variation—the number of engine/transmission combinations, wire harnesses, and exterior paint colors—that affect the sequencing of vehicles, the task variability facing production workers, and material handling requirements; and three measures—the number of total parts to the assembly area, the percentage of common parts across models, and the number of suppliers to the assembly area—that affect the administrative/coordination requirements for dealing with suppliers. **Product Design Age** is the weighted average number of years since a major model change introduction for each of the products currently being built at each plant, and serves as a partial proxy for manufacturability in the assembly area, under the assumption that products designed more recently are more likely to have been conceived with ease of assembly in mind than older products.

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[9] The two measures are very highly correlated (r = .81), since plants with above-average scores for Total Automation have generally directed most of their recent technology investment toward robotic technology. The results reported below, using the Robotic Index variable, are nearly identical when the Total Automation measure is used.

Regional Differences in Training Effort. The regional means in Table 1 provide the initial basis for evaluating the "comparative advantage" and "national institutions" hypotheses concerning national-level training differentials.[10] Plants in the newly industrialized countries (NIC) train *more* than U.S.-owned plants in North America and plants in Australia, suggesting that the hypothesis linking higher levels of training to advanced industrialized economies is not supported. The very high differentials in training effort among the three most industrialized groups of plants (in the United States, Europe, and Japan) call both the first and second hypotheses into question.[11] This variation suggests that the determinants of training go well beyond wage rates, since wage differentials among the United States, Japan, and Europe are much smaller than the training differentials.

Examination of Japanese-owned plants in North America (J/NA) and U.S.-owned plants in Europe (US/Eur) also challenges the hypothesis that the national infrastructure for education and training determines training levels, since both sets of "transplants" offer different amounts of training than locally owned plants—the J/NA plants train more than US/NA plants, and US/Eur plants train less than Eur/Eur plants. Another sign that training differentials reflect firm-level rather than national-level factors is the lack of significant differences in training effort between J/J and J/NA plants and between US/NA and US/Eur plants. These findings suggest that the "comparative advantage" and "national institutions" hypotheses are not supported, although a full test of national-level factors requires controls for other variables, as below.

Regression Analyses. Table 3 contains descriptive statistics and Table 4 reports the results of regression analyses with the Training Effort index as the dependent variable.

Equation (1) includes dummy variables for the regional groups in Table

[10] Examination of the distribution of the Training Effort variable shows that five plants are outliers above the sample mean—two Japanese-owned plants in Japan, one European-owned plant in Europe, and two plants in newly industrialized countries. These outliers account for the high standard deviation for these three regional groupings, and undoubtedly affect the regional means as well. Since we have no reason to believe that the data from these plants are incorrect, we judged that it was better to include them when calculating the sample mean, rather than excluding them. To test the impact of these outliers, all regression analyses (reported below) were repeated using log training effort as the dependent variable. The results were unchanged.

[11] While there is variation within the group of plants in Europe, which come from seven countries, it appears to be based on the company rather than the country. This is particularly striking with respect to Germany, which is often described as having very high levels of training. The two German plants in the sample train less than some plants in France, Belgium, Sweden, and Italy, although more than plants in Britain and Spain. Indeed, the level of variation within many of the regional groupings is impressively high.

TABLE 3

DESCRIPTIVE STATISTICS FOR REGRESSION ANALYSES
(n = 57)

Variable	Mean	S.D.
Training Effort	24.7	23.7
Scale	936	651
Model Mix Complexity	30.6	21.2
Parts Complexity	56.5	23.5
Product Design Age	4.7	3.3
Robotic Index	2.2	2.0
Use of Buffers	58.7	22.4
HR System	33.6	26.3
Buffers by HR System	371.3	626.4
Jpn/Jpn Dummy	0.14	0.35
Jpn/NA Dummy	0.07	0.26
US/Eur Dummy	0.07	0.26
Eur/Eur Dummy	0.17	0.38
NIC Dummy	0.19	0.40
Australia Dummy	0.10	0.31

1 to test the two national-level hypotheses, with the dummy for U.S.-owned plants in North America omitted to make it the comparison group. The results echo the comparison of means, with statistically significant differences in training level from the comparison group for Japanese-owned plants in Japan, European-owned plants in Europe, and plants in newly industrialized countries. Contrary to Table 1, the "Japanese transplant" dummy was not statistically significant, with a T-value of 1.62 ($p = .11$), but the sign of the coefficient for this and the other regional dummies (U.S.-owned plants in Europe and Australian plants) is in the right direction. Again, the "comparative advantage" and "national institutions" hypotheses are not supported. However, with an adjusted R^2 of .243, this equation does suggest that national/regional differences in training are pronounced.

Equation (2) tests the "technology" hypothesis by including the Robotic Index and the four control variables, and is also the "base case" for testing the other firm-level hypotheses. With a non-significant adjusted R^2 of .029 and coefficients for all variables that are indistinguishable from zero, the hypothesis about the relationship between advanced automation and training effort is disconfirmed. Clearly, plants with similar levels of robotics have very different training policies.

Equations (3)–(5) test the "flexible production systems" hypothesis, in three stages. In each case, an F-test is applied to the change in R^2 from the preceding equation, to see if the added variables boost predictive power.

TABLE 4

REGRESSION MODEL FOR TRAINING IN THE AUTOMOBILE INDUSTRY
(standard error in parentheses)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Jpn/Jpn Dum	36.7***	—	—	—	—	1.53
	(9.15)					(22.9)
Jpn/NA Dum	18.99	—	—	—	—	−2.03
	(11.7)					(14.8)
US/Eur Dum	1.14	—	—	—	—	11.6
	(11.7)					(12.4)
Eur/Eur Dum	16.1*	—	—	—	—	26.7***
	(8.55)					(9.70)
NIC Dum	18.5**	—	—	—	—	21.9***
	(8.31)					(9.27)
Aust Dum	−6.47	—	—	—	—	−11.9
	(10.1)					(10.5)
Scale	—	.008	.005	.007	.007	.002
		(.006)	(.006)	(.005)	(.006)	(.005)
Model Mix Complexity	—	.129	.021	.018	.034	.066
		(.170)	(.171)	(.161)	(.157)	(.158)
Parts Complexity	—	−.124	−.077	−.151	−.204	−0.369**
		(.176)	(.171)	(.163)	(.162)	(.173)
AgeCar	—	−1.46	.004	−.318	−.545	−1.89
		(1.13)	(1.28)	(1.21)	(1.18)	(1.21)
Robotic Index	—	.432	.536	−1.50	−1.58	−1.18
		(2.01)	(1.94)	(1.97)	(1.92)	(2.08)
Use of Buffers	—	—	.384***	.076	.112	.231
			(.176)	(.199)	(.196)	(.202)
HR System	—	—	—	.422***	.206	.105
				(.154)	(.191)	(.220)
Buffers by HRSys	—	—	—	—	.012**	.016**
					(.006)	(.008)
Adj. R^2	.243	.029	.095	.199	.237	.380
F for equation	4.0***	1.3	2.0*	2.9***	3.2***	3.5***
F for Change in R^2 from Preceding Equation	—	—	4.8**	7.5***	3.4*	2.9**

* = Statistically significant at .10 level; ** = statistically significant at .05 level; *** = statistically significant at .01 level.

Equation (3) adds the Use of Buffers index to the control variables, has an adjusted R^2 of .095 and is statistically significant. The Buffers index is significant at the 99 percent confidence level and has the expected sign, with more training associated with smaller buffers of inventory and repair space, consistent with the hypothesis about flexible production.

Equation (4), which adds the other production organization index, HR System, has an adjusted R^2 of .199, a significant increase from equation (3). With HR System and Use of Buffers both in the equation, only the former is significant, at the 99 percent confidence level. This is not surprising, given the high correlation (r = .65) between the two indices. This finding is also consistent with evidence from other analyses (not presented here) that some plants begin the transition to flexible production by reducing buffers but do not make corresponding changes in their HR policies (at least initially).

Equation (5) includes the interaction term, Buffers by HR System, to test whether the hypothesized integration of production policies and HR policies helps explain training levels better than the individual indices. The adjusted R^2 of this equation is .237, which represents a statistically significant increase over equation (4). Here only the interaction term is statistically significant (at the 95 percent significance level) and the individual indices are not. This is strongly supportive of the idea that training is linked to the overall "organization logic" of flexible production (and not just its bundle of HR practices) and provides the strongest evidence for this hypothesis.

Finally, equation (6) reintroduces the regional dummy variables from equation (1) to assess the relative explanatory power of different variables when all are included. The adjusted R^2 of .38 is a statistically significant increase over equation (5). The Buffers by HR System interaction term retains the same significance level. Of the regional dummy variables, those for European-owned plants in Europe and for newly industrialized countries are significant, as in equation (1), with positive coefficients. In fact, their coefficients are higher in equation (6), with greater statistical significance, than in equation (1). In other words, both of these regional groups provide higher levels of training than their approach to the production system (which is closer to mass production than flexible production) would predict.

But the regional dummy for Japanese-owned plants in Japan is not significant once the production system variables are included. Furthermore, the coefficient for the "Japanese transplant" dummy variable, which is not significant in either equation (1) or (6), drops dramatically in equation (6). The Japanese-owned plants appear to train a lot because they rely heavily on flexible production, while the U.S.-owned plants in Europe and the Australian plants appear to train very little because they follow traditional mass production practices and philosophies.

These results provide limited support for the view that differences in national practices affect the level of training, even aside from differences in production systems. In Europe, in particular, many countries have strong public policy support for extensive training, with the German apprenticeship model as the most notable example. But plants in Europe (whether European-owned or U.S.-owned) have not, for the most part, implemented flexible production. One explanation is that the volume producers in Europe (Volkswagen, Fiat, Renault) have used the past fifteen years to move closer to the high volume, standard product approach of mass production—a goal that proved elusive in earlier years, when production volumes were low and craft methods more strongly entrenched (Womack, Jones, and Roos, 1990). As a result, the *demand* for worker skills in European auto plants may be limited because mass production principles are used, even though the education and training infrastructure has produced an ample *supply* of those skills. On the other hand, U.S.-owned plants in Europe appear bound by U.S.-set policies and exempt from (or resistant to) host-country institutional pressures to boost training.

The case of the newly industrialized countries is equally intriguing. Plants in these low-wage countries, where absenteeism and turnover are typically high, are not expected to offer much training. Nevertheless, some auto assembly plants in these countries have achieved quality (if not productivity) levels comparable to those in the advanced industrialized countries, and they have been willing to make unusually high investments in training (if not wages) to achieve these results.

Discussion

These results support the popular hypothesis that U.S. firms tend to invest less in the development of human resources than their Japanese and European competitors. Moreover, this gap will not be automatically closed by greater investments in high technology. Training levels have virtually no relationship with the level of technology in these assembly plants, nor with a plant's scale, product mix, or parts complexity. Instead, these results suggest that two factors drive investments in training—the production strategy employed by the organization and some characteristics of the national environment of the parent firm.

The significance of the production organization indices, both separately and in interaction, suggests that one way to encourage training in U.S. firms is to support the diffusion of flexible production models that demand greater training. This raises a variety of issues about supply vs. demand for skills and training. The case of Europe shows that the presence of relatively high levels of training is not automatically associated with the adoption of flexible production systems. So public policies that boost the supply of skills through mandated training, in the absence of action by firms to adopt new approaches to organizing work, may not improve the demand

(and hence utilization) of skills.[12] On the other hand, if firms move toward flexible production and are not able to find an adequate supply of workers with the necessary skills in reading, math, and analytical problem-solving, the implementation of new work structures may be slowed or firms may have to assume the cost of remedial training.

This analysis implies that firm choices about production strategy will still be the primary determinant of training effort. The examples of Japanese-owned plants in North America and U.S.-owned plants in Europe, both of which train at very different levels than other plants located in the same region,[13] reveal how strong the influence of corporate-wide training policies is, compared with national-level institutional pressures.[14] Thus the role for public policy may lie primarily in encouraging the demand for skills by the firm. Policies that promote the adoption and diffusion of flexible production and new approaches to organizing work (often labeled "high performance" work systems) should have a positive byproduct of increasing the level of training.

While not addressed by these data, the *content* of training under flexible production has important implications for both firm-level and national-level training policy. Training prompted by national government policies or institutionalized throughout the national industrial relations system is more likely to emphasize the development of technical skills that are porta-

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[12] As European companies move toward flexible production, their highly trained workers may prove to be an important asset in the transition. However, this will depend on whether the skills of European workers are well-suited to the requirements of flexible production. The German apprenticeship-based approach to training and certification arguably produces excellent functional specialists, whereas flexible production appears to require multiskilled generalists.

[13] To test for a possible "ownership" effect on training, the regression analyses in Table 5 were repeated using dummy variables signifying the home region of the company that owns each assembly plant. For example, this categorization would group together plants from a U.S.-owned multinational (e.g., General Motors) located in the United States, Europe, Central and Latin America, and Australia. With U.S. company-owned plants as the comparison category, only the Japanese-owned dummy variable was significant in equation (1) and only the European-owned dummy variable was significant in equation (6). We concluded that the regional dummies used in Table 5 are preferable because the within-group variation among the U.S.-owned, European-owned, Japanese-owned, and Korean-owned groups is quite high. For example, the standard deviation for all U.S.-owned plants is 16.7, vs. 8.0 for U.S.-owned plants in North America and 12.7 for U.S.-owned plants in Europe.

[14] Ownership of a plant will only correspond to the nationality of a firm's management if expatriate managers are sent to run the plant—something that appears to be true for Japanese-owned plants in the U.S. but may not be true for U.S.-owned plants in Europe. The dummy variable for the Japanese transplants already captures the "nationality of management" effect for this group. At most other plants located out of the home region of their parent company, local managers feature more prominently in the plant management. A full test of the "nationality of management" hypothesis would require some threshold level that identifies when expatriates can be said to be managing the plant, or precise data on the mix of local and expatriate managers—not available in this data set.

ble across jobs and therefore taught, evaluated, and certified according to national standards. Training carried out entirely by the firm is likely to emphasize motivation as well as technical skill, and focus on firm-specific skills.

Flexible production plants appear to require some mix of general skills necessary for effective problem-solving (reading, math, and reasoning skills) and firm-specific skills related to the firm's technology and production system. Furthermore, because of their reliance on work teams, these plants are likely to emphasize interpersonal and communication skills as well.

Thus the training provided by firms using flexible production may yield some general skills that can be valuable in any job (e.g., those related to problem solving and functioning in a team) but will also develop firm-specific skills that are not portable. This is one reason critics of flexible production argue that extensive training may bring more benefits to management than to workers. Yet earning a portable certificate for technical skills based on national standards may be less valuable for workers, given the rapid pace of technical change and the firm specificity of much technical knowledge, than general skills in problem solving, working in teams, and communication. This suggests that public policy focused on training standards should emphasize not only technical skills but also the more broadly applicable cognitive and interpersonal skills that are commonly taught in flexible production settings.

We expect that the training effort differentials reported in this paper will narrow in the future, depending on the rate at which flexible production diffuses worldwide and whether public policy changes in various countries. In the United States, training has risen since 1989–90, when these data were collected, as an industry resurgence has allowed joint training funds between each of the Big Three companies and the UAW (Ferman et al., 1990) to be replenished and expanded. The test of whether or not this reflects a permanent increase in training effort by the Big Three will come in the next industry downturn, when training budgets are often cut.

If U.S. auto companies do act to boost training levels, as part of a gradual transition to flexible production, the biggest training gap to be filled by public policy will be in the area of basic skills—literacy and math. These skills form the foundation for training (both technical and non-technical) that firms will provide in support of flexible production. With the Big Three anticipating extensive hiring of young workers to replace retirees in the next ten years, their training decisions—and potentially the extent of their transition to flexible production—will be critically affected by whether or not they are able to find a sufficient supply of these skills.

Only the countries where the public education system provides these basic skills in ample quantity will be able to follow the desirable high-quality, high-variety, high-wage strategy in more than a few exemplar companies.

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