What's Driving the New Economy: The Benefits of Workplace Innovation

by
Sandra E. Black
and
Lisa M. Lynch

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Sandra E. Black and Lisa M. Lynch
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ABSTRACT

Using a unique nationally representative sample of U.S. establishments surveyed in both 1993 and 1996, we examine the relationship between workplace innovations and establishment productivity and wages. Using both cross-sectional and longitudinal data, we find evidence that high performance workplace practices are associated with both higher productivity and higher wages. Specifically, we find a positive and significant relationship between the proportion of non-managers using computers and productivity of establishments. We find that firms that re-engineer their workplaces and incorporate more high performance practices experience higher productivity. For example profit sharing is associated with increased productivity and employee voice has a large positive effect on productivity when it is done in the context of unionized establishments. These workplace practices appear to explain a large part of the movement in multifactor productivity over the period 1993-1996. When we examine the determinants of wages within these establishments, we find that re-engineering a workplace to incorporate more high performance practices leads to higher wages. However, increasing the usage of profit sharing results in lower regular pay for workers, especially technical workers and clerical/sales workers. Finally, increasing the percentage of workers meeting regularly in groups has a larger positive effect on wages in unionized establishments.

Sandra E. Black
Domestic Research Function
Federal Reserve Bank of New York
33 Liberty Street
New York, NY 10045
sandra.black@ny.frb.org

Lisa M. Lynch
Fletcher School of Law & Diplomacy
Tufts University
Medford, MA 02155
and NBER
lisa.lynch@tufts.edu

I. Introduction

With the recent release of historical revisions to productivity data from the Bureau of Labor Statistics, we know that during the 1990s average annual productivity growth in nonfinancial corporations in the U.S. was 2.7 percent. This rate is even higher than productivity growth experienced by these types of firms in the 1960s. Additionally, manufacturing productivity grew even faster at almost 4 percent annually. This growth in productivity has led many to argue that a “New Economy” is being created in the U.S. that is being driven by innovations in technology and by the evolution of new forms of work organization in the context of increased globalization. This “New Economy” is characterized by firms increasing their capital investments especially in information-technology software and hardware. In addition, more firms are adopting “knowledge-based” work processes in which an increasing proportion of non-managerial workers are involved in problem solving and identifying opportunities for innovation and growth. Some have argued that increased managerial focus over the 1980s-1990s on quality management, continuous innovation, incentive based compensation, and employee involvement programs has in turn raised the productive capacity of our economy. Data collected from a representative sample of businesses in the U.S. shows that by 1996 many employers have in fact adopted what are often labeled “high performance workplace practices” (see Figure 1).

However, there is limited causal evidence on the role of technology and workplace innovation in generating rising productivity during the 1990s. As a result, it is hard to forecast the potential sustainability of this “New Economy” into the future. Recent studies by Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) attempt to decompose labor productivity growth into contributions coming from capital deepening and multifactor productivity growth (the growth in output that can not be accounted for by changes in labor and capital inputs). These studies find for the U.S. during the 1990s that slightly more than one half of the growth in output in private nonfarm businesses can be explained by multifactor productivity growth. When one looks at the manufacturing sector alone during the 1990s one can see (Table 5) that multifactor productivity growth during the 1990s was an extremely important component of output growth in this sector. Therefore, getting a better understanding of what might be driving multifactor productivity growth would be an important step forward in understanding what is driving the "New Economy".

This paper seeks to inform the debate on the determinants of the rapid increase in productivity in the U.S. during the 1990s. Using a unique sample of U.S. businesses over the period 1993-1996 we examine the role of information technologies (especially computers) and other capital investment, workplace innovation (including team-work, employee involvement in decision-making and re-engineering activities, profit sharing), and worker characteristics (education, training, turnover, gender and race) on productivity.

We then explore how workers' wages have been impacted by innovations in workplace practices. In particular, we try to see if those practices which appear to raise productivity are also associated with higher earnings by workers. Examining the impact of workplace innovation on wages is important for two reasons. First, if workers are being asked to take on more responsibilities for generating innovation in the workplace, how are they being rewarded for this effort relative to the gains businesses experience from their input? Second, if firms find that they need to increase compensation substantially in order to implement many of these new workplace practices, does it become excessively costly for them to actually move from more traditional managerial practices to new forms of workplace organization?

For this study we use a unique nationally representative sample of manufacturing establishments, drawn from the Educational Quality of the Workforce National Employer Survey, EQW-NES. This survey is composed of two waves of interviews of representative samples of U.S. manufacturing and non-manufacturing establishments in 1993 and 1996. The first wave in 1993 included over 1,600 manufacturing establishments and the second wave in 1996 included over 2,500 establishments (including a panel of approximately 700 establishments). The survey has a higher response rate than most previous studies and contains very detailed information on specific employer practices and investments in new technology including computers.We match plant level practices with plant level productivity and wage outcomes and estimate production functions and wage equations using both cross sectional and longitudinal data. The existence of panel data allows us to control for unobserved time invariant establishment characteristics.

Consistent with our earlier work (Black and Lynch 1996 and 2001), we find that high performance practices do affect firm productivity. Specifically, we find a positive and significant relationship between the proportion of non-managers using computers and the productivity of establishments. We find that firms that re-engineer their workplaces to incorporate more high performance practices experience higher productivity. Profit sharing is also associated with higher productivity. In addition, we find that employee voice (proxied by the percentage of workers who regularly meet to discuss workplace issues) has a larger positive effect on productivity when it is done in the context of unionized establishments.

When we examine the determinants of wages within these establishments, we find that re-engineering a workplace to incorporate more high performance practices leads to higher wages. However, increasing the usage of profit sharing or stock options results in lower regular pay for workers, especially technical workers and clerical/sales workers. Finally, increasing the percentage of workers meeting regularly in groups has a larger positive effect on wages in unionized establishments.

II. Background Discussion

Workplace Innovation and Productivity.

Our work is not the first to examine the impact of workplace practices on the productivity of businesses, but much of the previous work on this topic has been limited in several ways.[1] Some of the most detailed and insightful work on the adoption and nature of new workplace practices has been done on a case study basis.[2] However, while these studies have provided us with a wealth of information on the chain of events that resulted in the adoption of new workplace practices, it is difficult to generalize these results to a broader spectrum of the economy.

One solution to this problem is to conduct a detailed intra-industry study of the adoption of workplace practices such as was done for the steel industry by Ichniowski, Shaw and Prennushi (1997). The advantage of intra-industry studies is that one can collect a high degree of detailed information on the variation of practices within a sector and see how they are related to variations in

[1]See Black and Lynch (2001) for a more detailed review of the literature.

[2]This includes for example work on auto plants by Krafcik (1988) and Womack, Jones and Roos (1991), a paper mill by Ichniowski (1992), two apparel plants by Berg, Appelbaum, Bailey, and Kalleberg (1996), and a regional phone company by Batt (1995).

performance.[3] By examining human resource practices associated with one specific production process it is possible to greatly reduce problems of underlying heterogeneity of production processes. Most of the intra-industry studies conclude that the adoption of a coherent system of new human resource management practices such as flexible job definitions, cross-training, and work teams, along with extensive reliance on incentive pay, results in substantially higher levels of productivity than more traditional human resource management practices (less flexible, close supervision, hourly pay). While these results represent an important contribution to the literature on workplace practices and productivity, it is again not easy to generalize these findings for a broader segment of the economy.

Another research strategy, which is applied here, is to survey a more representative sample of firms (typically cross section but also longitudinal) and examine the impact of workplace practices on broader measures of performance such as productivity or profitability. While a number of papers have examined this relationship and found a significant correlation between human resource management systems and various measures of business performance, this work has been limited by problems such as subjective measures of productivity, low response rates, and the use of indexes of workplace practices, which lead to ambiguities in interpretation.[4].

In earlier work (Black and Lynch 1996) using a unique representative survey of U.S. businesses, the Educational Quality of the Workforce National Employers Survey I (EQW-NES I), we

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[3]Other examples of intra-industry studies include work by Arthur (1994) on the steel industry, Kelley (1994 and 1996) on the machine tool industry, and Bailey (1993) and Dunlop and Weil (1996) on the apparel industry.

[4]See work by Ichniowski (1990),Huselid (1995), and Huselid and Becker (1996).

examined the impact of workplace innovation on labor productivity by estimating a standard cross section Cobb Douglas production function (separately for manufacturing and non-manufacturing) that was augmented by our measures of workplace practices, information technology, and human capital investments. In subsequent work (Black and Lynch 2001) we used panel data to estimate a Cobb Douglas production function with labor productivity as our dependent variable and capital/labor, materials/labor, year dummies, and 2 digit SIC industry controls interacted with year dummies for a matched data set of manufacturing establishments from the first round of the EQW-NES I survey and the Census Bureau's Longitudinal Record Database panel of manufacturing establishments covering the period of 1987-1993. The average residual over this period for each establishment was then used as a measure of the establishment fixed effect and was regressed on our measures of workplace practices, human capital investments, diffusion of computer usage and other employee and employer characteristics to determine their association with productivity. In this way we tried to see how the information on workplace practices we obtained in the EQW survey was related to which businesses did better or worse on average over the period 1988-1993.[5]

In both of these studies we found that workplace practices do matter, no matter how the production function was estimated. However, we found that what was associated with higher

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[5]One advantage of this two-step procedure relative to the estimation of the cross section production functions is that we can address the issue of biases in the estimates of the coefficients of capital, labor, and materials due to correlations with the firm specific-time invariant components of the error term. We did this using both within and generalized method of moments (GMM) estimators to address omitted variable and endogeneity bias. While the GMM estimator can help address endogeneity and measurement error biases when using panel data, biases can still arise in estimating the coefficients on the vector of workplace practices in the second step since we did not have panel information on workplace practices.

productivity was not so much whether an employer adopted a particular work practice but rather how that work practice was actually implemented within the establishment. For example, simply adopting a Total Quality Management system has an insignificant or negative impact on productivity unless the proportion of workers involved in regular decision making within the plant is also high. In other words, it is not so much what you say you do, but how you do it that matters.

We also found important differences across plants on the basis of the type of labor-management relations within the plant. Establishments with more traditional unionized labor-management relations including little or no direct participation of employees in decision making, had substantially lower productivity than unionized plants that had adopted new workplace practices, including incentive-based compensation and greater employee participation in decision making. In addition, these unionized plants performed much better than even non-union plants that had adopted similar high performance workplace practices.[6]

These findings suggest that establishment practices that encourage workers to think and interact in order to improve the production process are strongly associated with increased firm productivity. We found that the higher the average educational level of production workers within a plant is, the more likely the plant has performed better than average over the period 1988-1993. In addition, although the proportion of managerial workers who use computers had no impact on labor productivity, the

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[6]Workers may be more willing to participate in employee involvement programs if they feel the union will protect their employment security. Agreements made between managers and workers may not be legally enforceable so the presence of unions, as discussed by Malcomson (1983), can address incentive compatibility problems that may arise at the workplace. In addition, negotiations that management undertakes with workers about the introduction of new workplace practices are less expensive if the company only has to deal with union specialists rather than each individual worker.

greater the proportion of non-managerial workers who use computers, the higher was plant productivity.[7]

The finding that workplace practices increase productivity is consistent with the theoretical discussion presented in Freeman and Lazear (1995). Their work provides a theoretical basis for the presence and role of works councils but it could easily be applied to high performance workplace practices. In their model, firms can increase total rents by giving employees a voice in management and production decisions. However, they do so at a cost; the more voice they give to employees, the greater the share of rents the employees will appropriate. There is some socially optimal amount of voice/rent taking. Freeman and Lazear show that firms who are maximizing their own share of the rents and not total rents will under-provide "voice" to workers. Therefore we would expect to see positive

[7]In work that builds on our earlier research, Cappelli and Neumark (1999) use the EQW-NES data set to examine the relationship between productivity, wages, and workplace practices. However, their methodology is quite different from ours. They only examine manufacturing establishments in the 1993 and 1996 surveys who were also in existence in the Census Bureau's 1977 LRD. They then examine the impact of workplace practices on the change in labor productivity of these establishments over the period 1977-1993 and 1977-1996. As a result, any manufacturing establishment that was "born" after 1977 is excluded from their analysis. They do this to get around the problem of omitted variable bias associated with unobserved establishment characteristics. By assuming that no establishments in 1977 used any high performance practices (e.g., profit sharing, employee participation in decision making, benchmarking, investments in human capital, etc...) they argue that they can use values of workplace practices in 1993 or 1996 in a 'fixed effect' first difference model where the dependent variable is the difference in labor productivity between 1977 and 1993 or 1977 and 1996. This is a rather unusual and problematic choice of sample since a substantial part of the story of workplace innovation throughout the 1980s and 1990s has been the creation of "greenfield" sites such as SATURN, where firms were able to implement new forms of workplace organization in brand new facilities. To exclude these types of establishments from the analysis significantly reduces the generalizability of the results and may bias them against finding any effect of workplace practices on productivity.

effects (even on the margin) of these workplace practices on productivity and wages.[8]

While there are strengths and weaknesses associated with all of the above-mentioned empirical research, the primary advantage of our work is that we use a rich panel data set from a nationally representative survey of establishments to determine whether the impact of workplace innovation obtained at the firm-specific or industry-specific level hold more generally or not. Having observations on establishments at two different points in time is crucial because it allows us to control for unobserved time invariant establishment characteristics. The length of time between the two surveys is long enough for a significant number of changes in workplace practices to have occurred and short enough to minimize the problem of "births" and "deaths" of establishments that could limit the generalizability of our results. The survey (both the cross sections and the panel component) has a higher response rate than most previous studies, and it contains very detailed information on specific employer practices.

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[8]There is also a growing theoretical and empirical debate on the existence of synergies in bundles of human resource management practices. Milgrom and Roberts (1995) argue that the impact of a system of human resource practices will be greater than the sum of its parts because of the synergistic effects of bundling practices together. Kandel and Lazear (1992) argue that introducing a profit-sharing plan for all workers in a firm may have little or no impact on productivity unless it is linked with other practices that address the inherent free rider problem associated with corporate wide profit sharing plans. The empirical evidence on synergies is mixed, with Huselid (1995) and Ichniowski et. al. (1997) arguing that bundles matter more than individual practices and Delaney and Huselid (1996) finding no effect from bundling. In this paper we test for the existence of these synergies explicitly. In our earlier work, Black and Lynch (2001), we were able to interact a wide range of practices with each other to see if there are interaction effects beyond the own effect of specific HR practices. We believe that this is a less restrictive strategy than arbitrarily grouping our businesses into three or four types of HR practice bundles or using factor analysis to generate an index of HR practices. However, Ichniowski, Shaw and Prennushi (1997) present compelling evidence (for steel) that systems of practices are more important determinants of productivity than individual practices. As a result, they conclude that improving productivity requires substantial changes in a set of HRM policies, not marginal changes in any one area.

We test for the importance of synergies in human resource management practices, match plant level practices with plant level outcomes, and analyze the effects of these practices on objective measures of productivity by estimating production functions on both cross sectional and longitudinal data.

Workplace Innovation and Wages

When workplace innovations are introduced there are a variety of costs associated with these innovations that may, or may not, outweigh the productivity benefits. These include the costs of goods and services (e.g. consultants) associated with the workplace innovation, adjustment costs (lost output and training costs) and higher wages. So while workplace practices may have a significant impact on the productivity of businesses, what happens to the wages of workers in firms with these types of practices? In the second part of our paper we present some preliminary work that examines the benefits workers may or may not be receiving from working for employers who have innovated their workplace practices. This work will hopefully also shed light on some of the costs employers incur by implementing these innovations.

One might expect that those practices which raise productivity of the firm would have a positive impact on pay, especially if there is any applicability of the skills associated with working in high performance workplaces outside the firm. An obvious example of this would be premiums paid to workers' human capital including employer sponsored training. But non-managerial workers who have learned how to work in self-managed teams may also become more valuable to other employers as they acquire problem solving and interpersonal skills. In order to overcome resistance to change supervisors may have to be paid a wage premium to ensure that they actively participate in (rather than undermine) work practices that require them to be a facilitator of groups of workers engaged in problem solving. These worker groups might otherwise be viewed as a challenge to the authority and job security of a supervisor. Firms that are undergoing substantial re-organization (or re-engineering) may have to pay a “compensating wage differential” to make-up for the increased job insecurity associated with rapid work re-organization. At the same time, workplaces that are undergoing substantial change in work organization may also generate increased concerns about job security that may temper worker demands for increased wages. Finally, employers who introduce profit-sharing or stock options to their employees may at the same time lower average regular wages (excluding profit sharing) to ensure that profit-sharing or stock options create the appropriate incentives.[9]

Computers, Productivity and Wages

Finally, we are also able to examine the impact of computers on productivity and wages. To date, this remains a controversial issue. Research in the 1980s (e.g., Bailey and Gordon (1988)) found little impact of computers on trends in aggregate productivity growth and Oliner and Sichel (1994) argued that this was to be expected given that they represented such a small percentage of the capital

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[9]There has been relatively little work that has examined the impact of workplace innovation on the pay of workers. In Hellerstein, Neumark and Troske (1996) the authors match data from the 1990 Decennial Census with data on manufacturing employers from the Census Bureau’s Longitudinal Research Database. This combines detailed demographic information on workers in a sample of plants with information on plant-level inputs, outputs and labor costs. However, there is no information on workplace practices in either of these databases. Cappelli and Neumark (1999) using the EQW-NES (but for a restricted sample of manufacturing establishments that have been in existence since at least 1977) find some evidence that workplace practices such as benchmarking and total quality management are positively related to average labor costs per worker. But these studies do not examine changes in wages and how they are affected by changes in workplace practices over time, nor do they examine how the pay of different categories of workers (managers, supervisors, technical workers, clerical/sales workers and production workers) is impacted by these workplace practices.

stock. This is resulted in the so-called technology paradox that high-tech spending during the 1980s and 1990s did not seem to raise productivity. The recent upward revisions reported by the BLS for productivity data for the 1980s and 1990s may mean that this high-tech paradox was more of a data artifact than anything real. In fact, Oliner and Sichel (2000) and Jorgenson and Stiroh (2001) both find that a great deal of the productivity growth in the second half of the 1990s can be explained by information technology.[10] But computers may have more than just a direct effect on productivity of firms. As discussed in Bresnahan, Brynjolfsson, and Hitt (1999), information technologies can also have an important effect on the ability of firms to implement organizational changes such as reorganizing production and giving workers more power in decision making – the so-called spillover effect from investing in information technology. In one of the few empirical studies of investments in information technologies and organizational change, Bresnahan, Brynjolfsson, and Hitt (1999) find evidence for complementarities between technology, organizational changes and skills. Unfortunately their work uses just cross sectional micro data on workplace practices. Therefore, it is interesting to examine both the impact of computers and other workplace innovations to see their impact on productivity and wages.

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[10]In addition, researchers such as Brynjolfsson and Hitt (1993) who used micro-based data found a positive relationship between computers and productivity while Krueger (1993) found that workers who worked with computers were paid approximately 15 percent more than similar workers who did not work with computers. Doms, Dunne and Troske (1997), using plant-level data on businesses in SIC 34-38 that was matched with micro data on a sample of individuals within each of their establishments, found a positive relationship between computers and other advanced technologies on the one hand and pay and labor productivity on the other hand.

III. The Data

In order to understand the nature and importance of our contribution, it is useful to start with a description of the data set on which we will work. The first round of the EQW National Employers Survey was administered by the U.S. Bureau of the Census as a telephone survey in August and September 1994 to a nationally representative sample of more than 3,000 private establishments with more than 20 employees[11]. The survey represents a unique source of information on how employers recruit workers, organize work, invest in physical capital, and utilize education and training investments. The survey over-sampled establishments in the manufacturing sector and establishments with more than 100 employees. Public sector employees, not-for-profit institutions, and corporate headquarters were excluded from the sample. The target respondent in the manufacturing sector was the plant manager and in the non-manufacturing sector was the local business site manager. However, the survey was designed to allow for multiple respondents so that information could be obtained from establishments that kept financial information such as the book value of capital or the cost of goods and materials used in production at a separate finance office (typically at corporate headquarters for multi-establishment enterprises). The sample frame for the survey was the Bureau of the Census SSEL file, one of the most comprehensive and up-to-date listings of establishments in the United States. Although the sampling frame omits establishments with less than 20 employees, it captures establishments that employ approximately three-quarters of all workers in the U.S.

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[11]The first survey was designed by Lisa Lynch in collaboration with EQW Co-Directors Robert Zemsky and Peter Cappelli. The second survey included a subset of questions identical to this first round plus an extensive section on employers' school-to-work activities. The surveys were supported by the Office of Educational Research and Improvement, US Department of Education.

The response rate in the first round EQW National Employers Survey for manufacturing establishments was 75 percent. This is substantially higher than most other voluntary establishment surveys. Of the 1,831 manufacturing establishments who participated in the survey, not all respondents completed all parts of the survey by the interview cutoff date of October 1, 1994. Therefore, the final number of manufacturing establishments in the sample for which all parts of the survey were completed was 1,621. This represents a 66 percent 'completed' survey response rate.

A second survey was administered by the Census Bureau in August 1997[12]. There was oversampling of establishments in California, Kentucky, Michigan, Maryland and Pennsylvania and a subsample of establishments that had been contacted in the first round. The final sample of completed interviews for the second round of the EQW-NES included 2,479 manufacturing establishments, representing a 63 percent response rate. A panel of 766 establishments (both manufacturing and non-manufacturing) can be constructed between the two rounds of the EQW-NES. The panel response rate (for first round establishments who were contacted and completed the interview in the second round) was 74 percent. The second survey was considerably longer in duration than the first survey (close to 45 minutes). Therefore, in spite of the high overall response rate there is a high percentage of businesses that do not provide information on all questions asked including items such as the value of shipments and sales, the book value of the capital stock, the costs of materials, wages paid to workers and the proportion of workers trained. This will reduce the final sample sizes used for analysis in this paper.

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[12]For more detailed information on response rates for the EQW-NES II see the following internet address: http://www.irhe.upenn.edu/cgi-bin/cat.pl#nes1997.

IV. Empirical Results

Establishment Productivity

A limitation of our earlier work (Black and Lynch 2001) is that while we were able to match our survey with longitudinal information on labor, capital and materials, we did not have longitudinal information on workplace practices and technology. As a result, the estimated coefficients on workplace practices and technology may be biased. These biases may be due to correlations between the second stage regressors and unobserved time invariant plant level characteristics. Although we believe that the method we used in our earlier work extracted a substantial part of the previously unobserved fixed effect and that many of the endogeneity issues are related to labor, capital and materials, these potential biases may have affected our previously reported estimates of the impact of workplace practices on labor productivity.[13] Given that we now have two waves of survey data, we are able to address some of these concerns.

1996 Cross Section Results

As a starting point, we first used the second wave of the survey (EQW-NES II) and estimated cross-section production functions to examine whether the impact of workplace practices, technology

[13]An example of an omitted variable that may be correlated with our workplace practices and consequently generate biases is managerial quality. It may be the case that the presence of good managers is more likely to be observed in firms with high performance workplace practices. Therefore, what looks like an effect of workplace practices on productivity is just good management. If it is true that good managers are those who adopt incentive-based compensation, get a higher proportion of their workers involved in decision making, and train a higher proportion of workers to use computers, then the fact that we are able to include these variables explicitly as regressors in our analysis means that there may not be much unobserved managerial quality left. However, the coefficients on workplace practices will capture the combined effects of the practice itself and the quality of management. These two effects should be accounted for separately.

and worker characteristics on labor productivity in 1996 are similar to those estimated using the 1993 data (see Black and Lynch 1996, 2001). These equations are of the form:

(1) $\ln(Y/L)_i = \alpha \ln(K/L)_i + \beta \ln(M/L)_i + \delta Z_i + \epsilon_i$

and

(2) $\ln(Y/P)_i = \alpha \ln(K/P)_i + \beta \ln(M/P)_i + \gamma \ln(N/P)_i + \delta' Z_i + \epsilon_i$

where ϵ_i is an error term and δ' is a vector of coefficients on Z_i which are establishment specific workplace practices and characteristics of employees such as education and turnover. In equation (1) L is the sum of all workers and in equation (2) we differentiate between production workers (P) and non-production workers (N).[14]

We augment the standard Cobb Douglas production function by allowing productivity to depend upon workplace practices, plant specific human capital measures, the diffusion of information technology, employee turnover rates, age distribution of the capital stock, and other characteristics of the establishments using data from the EQW-NES II. Since we are trying to understand the tremendous growth in manufacturing productivity during the 1990s, we only focus only on manufacturing firms in this paper. Total sales, capital, and material numbers for manufacturing establishments in our survey are adjusted using deflators from the NBER Productivity Database assembled by Eric Bartelsman and Wayne Gray (1996) and updated recently with the support of Randy Becker at the Census Bureau. (See the Data Appendix for more details).

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[14]Note that we are constraining the model here to assume constant returns to scale but we will test this assumption in our empirical work.

One problem with the EQW-NES is that while there is a very high overall response rate, questions such as the total value of shipments or sales or the book value of the capital stock had high non-response rates. But by design, many of the manufacturing establishments in the EQW survey could be matched with the Census Bureau's LRD. In this way we are able to replace missing data from the EQW survey with data from the LRD. This allows us in the cross section analysis to nearly double our sample size from 760 to 1493 observations[15].

Table 1 presents the results when we use the 1996 survey and estimate cross section production functions (equations 1 and 2 above). The results presented in this table are largely consistent with our earlier work. In Column 1 of Table 1 we find estimated coefficients on capital, labor, and materials that are reasonable and similar to those in our previous work. This carries through when we divide labor into production and non-production workers and use sales/production workers as our dependent variable (Columns 2 and 3).[16]

Consistent with our earlier work, we find a positive and significant relationship between the proportion of non-managers using computers, suggesting that the diffusion of information technology is associated with higher productivity. In addition, having a greater proportion of total capital stock 1-4

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[15]We were concerned how correlated LRD data on sales and employees would be with EQW data. Therefore we compared values on sales, capital, material costs, and employment from the LRD and EQW. We had to construct a book value of the capital stock for the LRD which we did following Black and Lynch 2001. We found the following correlation coefficients — for sales 0.91, for capital 0.79, for material costs 0.67 and for employment 0.96. We always include a dummy variable in our estimation to indicate if the data on sales, capital, materials are obtained from the LRD or not and this is never significant.

[16]The imposition of constant returns to scale is always accepted.

years old is positively associated with productivity. Note that the share of the capital stock less than one year old is insignificant which may indicate a “learning curve” associated with the introduction of new technology. In results not reported here we find that the proportion of managers using computers does not have a significant impact on establishment labor productivity.

We find that some worker characteristics do have an impact on productivity. For example, the overall educational level of the establishment (constructed by using the average education of each of five occupational categories and then using employment shares as weights) is positively related to labor productivity but when we divide labor into production and non-production workers in equations 2 and 3, education of non-production workers is not statistically significant. However, the average education of production workers is significant but negatively related to labor productivity. This may be due to the fact that we are not able to control for average experience or tenure in our equations. Higher turnover, as proxied by the proportion of the workforce with tenure less than one year, does appear to significantly reduce productivity as it did in our earlier work using 1993 data. Finally, the proportion of workers who are women or minorities has no impact on labor productivity.

When we turn to workplace innovations we find that high performance workplace practices and employee voice appear to be significantly related to establishment productivity. Incentive schemes do matter, as establishments that offer profit sharing or stock options to any employees as a part of the compensation package have higher productivity. Re-engineering[17] is significant in some of the

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[17]Re-engineering is whether or not the establishment has engaged in a major reorganization at any time over the past three years. Therefore, this variable is more appropriately considered as a change variable that we would expect to have a more significant impact in the fixed effect estimation. Management consultants typically define re-engineering as moving away from organizing work on the

specifications but bench-marking appears to have little impact on labor productivity. In terms of the impact of employee voice on labor productivity, we find that unionized businesses have higher productivity. However, increasing the proportion of workers that meet on a regular basis has a negative effect on productivity, although this is usually insignificant. When we examine the interaction of workplace practices in equation 3 of Table 1 we find that unionized establishments with profit sharing have lower labor productivity while unionized establishments that underwent a re-engineering effort have higher labor productivity. While the profit sharing result is a bit perplexing, the unionization interaction with re-engineering is consistent with the idea that unions provide the necessary job security to make workplace reorganization effective.

Panel Data Production Functions

In spite of the fact that we are able to control for many more managerial practices than most previous studies on productivity, our cross section estimates may still be subject to omitted variable bias (see Griliches and Mairesse 1995) due to unobserved establishment characteristics. Although we believe that the detailed information contained in our establishment survey allows us to extract much of the previously unobserved establishment specific effect, one can remove any remaining biases due to omitted but time-invariant establishment-specific effects using panel data. Consider the following equation:

(3) $Y_{it} = \text{"} \, \text{'}X_{it} + *\text{'}Z_i + <_i + ,_{it}$

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basis of functional silos and relying instead on cross-functional operations and communications. Re-engineering efforts are not necessarily independent of technological change but are focused on the organization of work. When we drop re-engineering from the cross section none of the other reported coefficients or effects change.

where Y is sales per production worker; " ' is a vector of coefficients on capital per production worker, materials per production worker, and the number of nonproduction workers per production worker; *' is our vector of coefficients on workplace practices from the EQW-NES survey; $<_i$ is an unobserved time invariant establishment fixed effect; and $,_{it}$ is the idiosyncratic component of the error term. Since we have two years worth of data, if we take deviations from an establishment's mean or, equivalently, take first differences of equation (3), all firm observed and unobserved time invariant fixed effects drop out and we can remove the bias in estimating the coefficients in vectors " ' and *' that occurs because of the omission of the establishment fixed effect. We are thereby able to exploit the panel nature of our data set and obtain estimates based on changes in workplace practices and how they are related to changes in establishment productivity.

Table 2 presents the results when we use our two waves of the EQW-NES survey to estimate equation 3 allowing for establishment fixed effects. The dependent variable is the difference in labor productivity across the two surveys and all of the explanatory variables are in first differences. The sample size is smaller (284 establishments) because we are restricted to using only those establishments that completed the survey in both years and had data on all variables in each survey year. The findings are broadly consistent with those presented in Table 1, which is perhaps surprising given that our results on the effect of workplace innovations are identified using their changes over a three-year period. If there are few changers over this period it may be difficult to find any significant effect. In fact, we found considerable movement in workplace practices over this three year period of time. For example, a third of the firms change their use of benchmarking, the number of managerial levels, the percent of workers in self-managed teams or the percentage of workers meeting regularly. These changes are not all in the same direction. For example there are almost as many firms between 1993-1996 deciding to adopt benchmarking as there are others dropping it.

Our estimated coefficients on capital and materials are consistent with previous research and are all statistically significant with the expected sign. In addition, we again find that information technology matters, as the proportion of non-managers using computer is positively related to labor productivity and statistically significant.[18] In terms of the impact of worker characteristics on productivity we find little effect of the education on productivity, but this is likely due to the fact that the average educational level was virtually unchanged over this period. Although not reported here, we have also estimated fixed effects productivity equations including the proportion of non-managerial workers trained[19]. We did find a positive and marginally significant relationship between training and establishment productivity, but a large non-response rate reduced our sample by approximately 30 percent. For this reason, we report the results excluding the training variables. As in the cross section results, we find that higher worker turnover has a negative impact on labor productivity.

Again, workplace practices do matter. We find that firms that re-engineer their workplaces experience higher labor productivity even after control for time invariant fixed effects, but now we find no impact of profit sharing and/or stock options on labor productivity. In addition, we find after controlling for fixed effects that increased usage of self-managed teams is associated with lower labor

[18]We did not include the age distribution of the capital stock in the fixed effects specification because we expect very little variation in this given the construction of this variable; as a result, any variation we do see would likely reflect noise in the measurement.

[19]We also included a measure of job rotation that was never significant in any of the productivity equations.

productivity.[20]

Finally, when we examine interaction effects we find that unionized establishments with a higher proportion of workers meeting regularly in groups to discuss workplace issues are also more productive. This suggests that synergies may exist between workplace practices.

Wages

Given that we have established a relationship between workplace practices and firm productivity using both the cross-section and panel data variation, we next turn to see whether or not the benefits to productivity that firms experience with these practices are shared with workers. In particular, must establishments compensate workers for their increased involvement in the production process and for incurring the risk associated with profit sharing forms of compensation? To examine this, we estimate analogous equations using the log of the average establishment hourly wage as the dependent variable instead of labor productivity. We can then examine the relationship between workplace practices and wages.

Table 3 presents estimates from cross-section wage equations using the 1996 survey data.[21]

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[20]This could be due to the fact that some workplace practices, when adopted, take a while to improve productivity. Consistent with this idea is the negative (although not statistically significant) coefficient on the interaction re-engineering and the percentage meeting to discuss workplace practices. Time spent in meetings associated with self-managed teams or problem solving could reduce productivity in the short run but have a positive impact on productivity in the longer run.

[21]Note the sample size in Table 3 for all workers is smaller than the sample size for the cross section productivity equation in Table 1. This reflects the fact that not all firms provided wage information. But the sample here is not a subset of establishments from Table 1 because those businesses that did not provided information on sales or capital stock but did provide information on wages would be included here. We report sample means in the first column so that one can see that even though these are not the same sample of establishments, the average characteristics are virtually

This is analogous to our cross-section production functions in Table 1 but with the average hourly wage, first at the establishment level and then by occupation within the establishment, as the dependent variable. The relationships we observe are quite similar to those we see when estimating the impact on productivity, which suggests that these establishments do need to compensate the workers for participating in these workplace practices which increase productivity. Columns 2 and 3 present the results when the dependent variable is the log of the average wage in the establishment. Column 2 shows that, consistent with the literature using individual level data, higher average education in the establishment is associated with higher wages; the magnitude suggests that a one year increase in average education raises wages by 11%. Larger establishments pay higher wages, and establishments with more women pay lower wages. Establishments with more turnover also pay lower wages.

Stock options and profit sharing as a part of the compensation package for any employee are associated with higher regular wages. Workers appear to also be compensated for using more advanced technology; the more non-managers using computers, the higher wages are. Unionized employers pay about 10% more than non-unionized businesses and employers that report that communication skills are a high priority in recruitment also pay their workers more.

When we allow for interactions between workplace practices (column 3), we see that the results are similar. In addition, we see that when an establishment has a higher percentage of workers meeting regularly in groups *and* the firm is unionized, wages are higher. This is entirely consistent with what we find with respect to establishment productivity.

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the same in Tables 1 and 3.

Columns 4 through 8 present the results when we examine the average wage in each establishment by occupational group, where the occupation groups include managers, supervisors, technical workers, production workers, and clerical/sales workers. The results are relatively consistent across occupations; however, there are some notable exceptions. The percentage of non-managers using computers only matters for the wages of supervisors and production workers. Increased training of managers and supervisors raises their wages, but increasing the proportion of workers trained in any of the other occupational categories appears to have no impact on their wages. Supervisors are paid more if they work in unionized establishments and establishments that have experienced a high degree of work reorganization combined with a high participation level of workers in regular meetings to discuss workplace issues. Since typically supervisors play the role of facilitators in these groups this suggests that those firms that have substantially “changed the rules of the game” for supervisors are also paying a significant wage premium to them. Production, clerical and sales workers that are working for unionized firms that have a high proportion of workers involved in regular meetings also have higher wages compared to other workers[22].

Wages with Panel Data

Since we have information on wages paid in both 1993 and 1996, we are also able to examine how changes in worker characteristics and workplace practices are related to wage growth in the establishment. Table 4 presents these results, first looking at the average wage in the establishment and

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[22]We also included the percentage of workers in job rotation in all equations. This variable is never significant expect in the wage equation for managers where it is associated with a higher rate of pay.

then breaking it down by occupation.

Despite larger standard errors (probably due to the increased measurement error induced by looking at first differences), the results using the panel are roughly consistent with our cross section findings. Columns 2 and 3 show the results when we consider the average wage of the establishment both without and with interactions. We find that higher average education in an establishment leads to higher wages; increasing education by one year leads to more than 5% wage growth. But now we see that re-engineering a workplace to incorporate more high performance practices lead to higher wages of about 7%, but this effect is offset somewhat for firms with a high percentage of workers meeting regularly in groups . Again, this is consistent with the idea that the implementation of these practices is costly and it takes time before we see wage or productivity effects. Increasing the use of profit sharing or stock options results in slightly lower regular hourly pay for workers and this is statistically significant for clerical/sales workers. Notice that this is a sign switch from the cross section results reported in Table 3.

Finally, increasing the percentage of workers meeting regularly in groups has a larger positive effect on wages in the presence of unions, again consistent with the productivity findings.

When we look at individual occupations, we find that education has a significant and positive relationship to wages for all groups except production workers and supervisors. In addition, increasing the proportion of managers trained over the period 1993-1996 has a positive and significant impact on wages of managers and increasing the proportion of clerical and sales workers trained raises their wages as well. In general, changes in workplace practices seem to have a large impact on the wages of supervisors, production and sales/clerical workers.

V. Conclusion

During the period 1993-1996 we find that U.S. manufacturing employers have been actively engaged in workplace re-organization and that these changes in workplace practices, along with increasing diffusion of computers, have played a significant role in the recent rise in manufacturing productivity. While manufacturing firms are enjoying the benefits of these technological and managerial innovations, workers appear to also be sharing some of these gains in the form of higher wages -- a "win-win outcome". More specifically, we find that increasing the percentage of non mangers using computers, undergoing re-engineering, or increasing employee voice all increase both productivity and wages. This makes sense if the augmented Cobb-Douglas function we have used here provides a good description of production and firms hire workers competitively.[23] But not all innovations impact productivity and wages in the same way or even necessarily in the expected way. For example, businesses that increase the proportion of workers in self-managed teams appear, at least in the short run, to have lower productivity and surprisingly pay workers higher wages. It is interesting to note that the usage of self-managed teams was one of the few workplace practices that we did not see much change in over the period 1993-1996 and this result may explain why. Finally, establishments with a great deal of employee involvement and re-engineering going on at the same time have lower productivity (although not statistically significant) while workers in these types of businesses are paid significantly lower wages.

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[23]Note that we are not explicitly testing for the equality of coefficients here but rather just examining the direction of effects.

At the beginning of this paper we discussed how important multifactor productivity has been during the 1990s in terms of driving output growth, especially in the manufacturing sector. We can use our estimates of the impact of workplace practices on labor productivity in a growth accounting framework and see how much of overall growth in manufacturing our measures of workplace innovation can account for over the period of 1993-1995. We present these calculations in Table 5 along with the figures reported by the BLS to "benchmark" our findings with their numbers. As seen in this table, the sample of EQW manufacturing establishments experienced very similar output growth over the period 1993-1996 as reported by the BLS for the country as a whole. The BLS reports that output growth in manufacturing grew at a compound average annual growth rate of 4.2 percent between 1993-1996. We find a rate of 4.7 percent using the EQW cross sections over the same period. The BLS reports that combined inputs (capital, labor and materials) grew 2.3 percent over this period and using the estimated coefficient from Table 2, equation 3 as shares we find inputs grew 3.2 percent in the EQW survey. As a result, multifactor productivity grew 1.9 percent in the BLS reported figures and 1.6 percent using EQW data. The advantage of the EQW surveys, however, is that now we can use our estimated coefficients and calculate the impact of workplace innovation on multifactor productivity. We find that they contributed 1.4 percent per year. In other words, workplace practices and re-engineering efforts accounted for approximately 30 percent of output growth in manufacturing over the period 1993-1996, or 89 percent of multifactor productivity. Though 1.4 percent may sound high, many of our workplace practices such as re-engineering reflect both technological as well as organizational changes. Nevertheless, we believe that this accounting exercise indicates that understanding workplace innovation can go some way in explaining recent trends in multifactor productivity.

In future work, we plan to extend this analysis to examine in greater detail the interaction between investments in computers and workplace innovation, investigate if the impact of these workplace practices is similar in the non-manufacturing sector, and pursue the issue of synergies in workplace human resource management practices in more detail. Understanding whether or not the recent rise in productivity growth is sustainable into the future will also require researchers to continue case studies and intra-industry analyzes that provide a deeper understanding of the processes firms are employing such as re-engineering and the barriers firms are facing to increase their productivity. However, at the moment, understanding the relationship between high performance workplace practices and firm productivity and wages can provide a valuable first step towards understanding our New Economy.

Data Appendix

The price deflators for shipments were constructed from 5-digit product deflators from BEA using the Bartelsman, Becker and Gray (2000) data set. These are largely created from the Bureau of Labor Statistics' (BLS) industry-based producer prices which are extrapolated backwards using the old BLS product prices. These data contain the BEA's computer deflator which is adjusted for quality using hedonic techniques.

The capital deflator is created by first generating a 3-digit industry real net capital stock value. The 3-digit data are converted to the 4-digit level by assuming that the industry-asset type flows are the same for all 4-digit industries within a 3-digit industry. With this information, 4-digit investment deflators are created for equipment and structures separately. Again, this deflator also incorporates the hedonic adjustment for quality changes in computers.

The materials deflator is created by averaging together price deflators for 529 inputs (369 manufacturing industries and 160 non-manufacturing industries), using as weights the relative size of each industry's purchases of that input in the Input-Output Tables. The inflation in materials prices is calculated as a Tornquist index (weighting each product's inflation rate by the average of the previous and current-year's shares in total materials used).

The energy price deflator is based on each industry's expenditures on six types of energy (electricity, residual fuel oil, distillates, coal, coke and natural gas). These six types of energy represent 94.6 percent of all energy expenditures by the manufacturing sector in 1976. They are a majority of the energy costs for all but one industry, and over 90 percent of energy costs for 300 of the industries.

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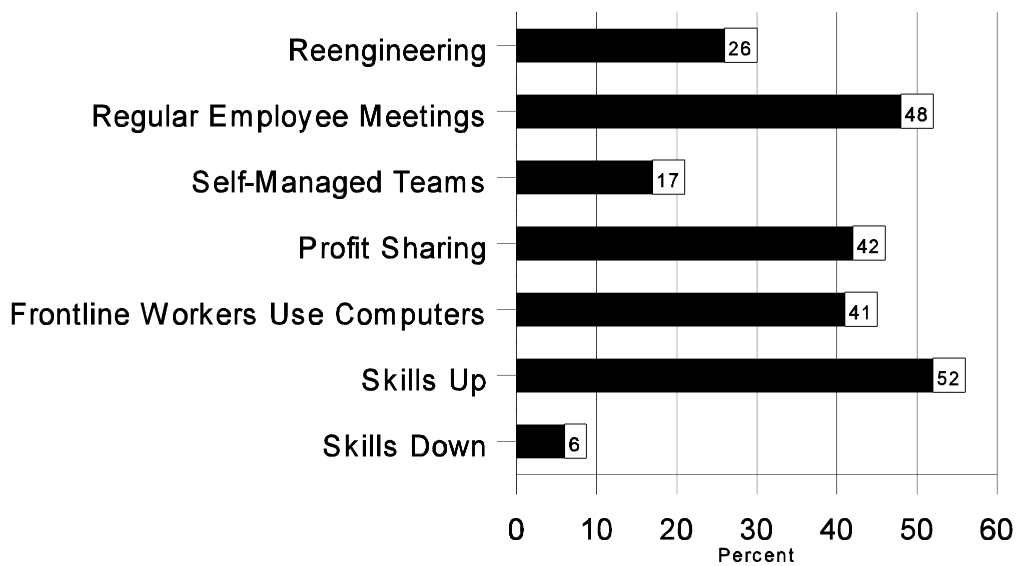
Figure 1: Incidence of Workplace Practices



Source: EQW 2nd Round Survey. Weighted data on U.S. establishment practices in 1996. Definitions: Reengineering - any reengineering efforts over the past three years; regular employee meetings - % of establishments reporting 75% or more of workers meeting regularly to discuss workplace issues; self managed teams - % of employers reporting 25% or more of their employees in self-managed teams; and frontline workers using computers - % of businesses reporting that 75% of more of their frontline workers use computers. Text of the survey and a public use version of the data are available on the Internet at www.irhe.upenn.edu/~shapiro.

Table 1: Determinants of Labor Productivity: 1996 Cross Section
T-statistics in parenthesis

Variable	Mean (s.d.)	Eq. 1 Coefficient (t-statistic)	Eq. 2 Coefficient (t-statistic)	Eq. 3 Coefficient (t-statistic)
Ln (Capital/Workers)		0.133** (10.84)	0.138** (11.108)	0.137** (11.092)
Ln (Materials/Workers)		0.476** (34.2)	0.483** (34.614)	0.483** (34.573)
Ln (Nonproduction/Production)			0.286** (17.33)	0.286** (17.321)
Technology				
Share of Equip < 1 yr.	0.116 (0.142)	0.115 (0.962)	0.094 (0.775)	0.095 (0.779)
Share of Equip 1-4 yr. old	0.294 (0.222)	0.199** (2.496)	0.231** (2.87)	0.221** (2.737)
Proportion Non-Managers using Computers	0.414 (0.364)	0.288** (5.438)	0.267** (5.021)	0.277** (5.165)
Worker Characteristics				
Ln (Average Education)	2.54 (0.082)	0.693** (2.90)		
Ln (Avg Ed Nonproduction Workers)	2.62 (0.077)		0.117 (0.497)	0.150 (0.636)
Ln (Avg Ed Production Workers)	2.47 (0.113)		-0.33 (-1.988)	-0.349** (-2.101)
Turnover (proportion employees < 1 year)	0.149 (0.157)	-0.428** (-3.731)	-0.392** (-3.377)	-0.376** (-3.239)
Proportion employees Women	0.375 (0.247)	-0.066 (-0.846)	-0.046 (-0.589)	-0.054 (-0.683)
Proportion employees Minority	0.272 (0.260)	0.070 (1.047)	0.078 (1.148)	0.085 (1.262)
Use of High Performance Work Systems				
Re-engineering	0.376 (0.484)	0.061* (1.676)	0.062* (1.679)	0.047 (0.764)
Benchmarking	0.332 (0.471)	0.001 (0.024)	0.005 (0.145)	0.007 (0.200)
Number of Managerial Levels	2.63 (1.92)	-0.003 (-0.389)	-0.009 (-1.053)	-0.010 (-1.178)
Proportion workers in self-managed teams	0.151 (0.289)	0.024 (0.396)	0.070 (1.142)	0.089 (1.262)

Profit sharing or Stock options	0.516 (0.499)	0.103** (2.936)	0.105** (2.947)	0.167** (3.991)
Employee Voice				
Unionized	0.304 (0.460)	0.072* (1.816)	0.092** (2.283)	0.168** (2.338)
Proportion Workers meeting regularly in Groups	0.524 (0.436)	-0.061 (-1.525)	-0.007* (-1.655)	-0.054 (-1.008)
Recruitment Strategies				
Grades a top priority in recruitment	0.163 (0.369)	-0.019 (-0.412)	-0.020 (-0.425)	-0.012 (-0.258)
Communication a top priority in recruitment	0.560 (0.497)	0.008 (0.213)	-0.010 (-0.287)	-0.008 (-0.208)
Interaction Terms				
Union*profit sharing	0.169 (0.375)			-0.218** (-2.904)
Union*re-engineering	0.129 (0.336)			0.121* (1.60)
Union*%meet	0.147 (0.324)			0.011 (0.124)
%meet*re-engineering	0.206 (0.371)			-0.041 (-0.506)
Union*% in self-managed teams	0.041 (0.158)			-0.100 (-0.736)
N =	1493	1493	1493	1493
Adjusted R^2 =		0.645	0.822	0.823

Estimated equations also include a constant term, 2-digit SIC industry controls, and a dummy if the establishment is part of a multi-establishment firm.

** denotes significance at the 5% level.
* denotes significance at the 10% level.

Table 2: Determinants of Labor Productivity: Fixed Effects Model (1996-1993)
T-statistics in parenthesis

Variable	Mean (s.d.)	Eq. 1 Coefficient (t-statistic)	Eq. 2 Coefficient (t-statistic)	Eq. 3 Coefficient (t-statistic)
Ln (Capital/Workers)		0.176** (2.099)	0.185** (2.391)	0.194** (2.544)
Ln (Materials/Workers)		0.259** (3.315)	0.277** (3.604)	0.274** (3.675)
Ln (Nonproduction/Production)			0.301** (4.665)	0.300** (4.743)
		Technology		
Proportion Non-Managers using Computers	0.351 (0.317)	0.296** (2.043)	0.345** (2.442)	0.363** (2.564)
		Worker Characteristics		
Ln (Average Education)	2.52 (0.07)	-0.70 (-1.071)		
Ln (Avg Ed Nonproduction Workers)	2.63 (0.069)		-0.352 (-0.525)	-0.457 (-0.674)
Ln (Avg Ed Production Workers)	2.47 (0.070)		-0.909* (-1.802)	-0.718 (-1.342)
Turnover (proportion employees <1 year)	0.109 (0.118)	-0.932 (-1.364)	-1.057* (-1.65)	-1.085* (-1.716)
Proportion employees Women	0.349 (0.214)	0.704 (1.198)	0.722 (1.234)	0.813 (1.381)
Proportion employees Minority	0.272 (0.252)	-0.255 (-1.069)	-0.168 (-0.670)	-0.117 (-0.453)
		Use of High Performance Work Systems		
Re-engineering	0.426 (0.495)	0.205** (2.667)	0.201** (2.619)	0.312* (1.72)
Benchmarking	0.408 (0.492)	-0.045 (-0.491)	-0.034 (-0.370)	-0.04 (-0.421)
Number of Managerial Levels	2.71 (2.12)	0.003 (0.200)	0.001 (0.072)	-0.003 (-0.176)
Proportion workers in self-managed teams	0.172 (0.300)	-0.545** (-2.278)	-0.536** (-2.242)	-0.535** (-1.968)
Profit sharing	0.63 (0.483)	0.041 (0.673)	0.042 (0.647)	0.017 (0.221)
		Employee Voice		

Unionized	0.377 (0.485)	0.23 (1.218)	0.28 (1.394)	-0.148 (-0.490)
Proportion Workers meeting regularly in Groups	0.577 (0.430)	-0.075 (-0.865)	-0.078 (-0.879)	-0.172 (-1.598)
		Interaction Terms		
Union*profit sharing	0.232 (0.423)			0.141 (1.014)
Union*re-engineering	0.162 (0.369)			0.068 (0.442)
Union*%meet	0.190 (0.356)			0.408* (2.117)
%meet*re-engineering	0.249 (0.400)			-0.226 (-1.095)
Union*% in self-managed teams	4.26 (13.22)			0.179 (0.543)
N =	284	284	284	284
Adjusted R^2 =		0.673	0.797	0.798

Estimated equations also include a constant term.
** denotes significance at the 5% level.
* denotes significance at the 10% level.

Table 3: Wage Equation, cross section 1996
T-statistics in parenthesis

Variable	Mean (s.d.)	All Workers	All Workers	Managers	Supervisors	Technical Workers	Production Workers	Clerical/Sales Workers
Dependent variable: ln (avg. wage)								
Technology								
Share of Equip < 1 yr.	0.102 (0.118)	0.044 (0.601)	0.043 (0.591)	0.078 (0.581)	-0.089 (-0.993)	0.071 (0.689)	0.030 (0.340)	0.039 (0.436)
Share of Equip 1-4 yr. old	0.263 (0.197)	0.049 (1.067)	0.052 (1.145)	0.270** (3.187)	0.118** (1.973)	0.099 (1.519)	-0.025 (-0.459)	0.010 (0.160)
Proportion Non-Managers using Computers	0.323 (0.309)	0.075** (2.445)	0.073** (2.365)	4.66e-04 (0.008)	0.082** (2.072)	0.064 (1.516)	0.157** (4.208)	0.062 (1.565)
Worker Characteristics								
Avg. Education	12.5 (0.9)	.11** (10.115)	.11** (10.134)	.036** (2.757)	.019** (2.237)	.05** (6.956)	.028* (1.946)	.045** (4.400)
Proportion of Employees Trained (within occupation)				0.09* (1.795)	0.09** (2.832)	-0.03 (-0.878)	-0.01 (-0.270)	0.002 (0.083)
Turnover (proportion less < 1 yr.)	0.138 (0.142)	-0.230** (-3.560)	-0.232** (-3.569)	-0.017 (-0.142)	-0.059 (-0.728)	-0.168* (-1.830)	-0.402** (-5.329)	-0.227** (-2.774)
Proportion employees Women	0.342 (0.212)	-0.367** (-7.996)	-0.368** (-8.025)	-0.167* (-1.896)	-0.300** (-4.938)	-0.317** (-4.493)	-0.493** (-8.749)	-0.258** (-4.267)
Proportion employees Minority	0.245 (0.257)	0.028 (0.786)	0.029 (0.816)	0.139** (2.067)	0.083* (1.780)	0.123** (2.315)	-0.040** (-1.984)	0.143** (3.086)
Use of High Performance Work Systems								
Re-engineering	0.386 (0.487)	0.005 (0.290)	0.002 (0.052)	-0.048 (-0.806)	-0.055 (-1.301)	-0.032 (-0.670)	-0.041 (-1.055)	0.008 (0.198)
Benchmarking	0.344 (0.475)	0.018 (0.962)	0.017 (0.898)	0.036 (1.110)	0.031 (1.328)	0.027 (1.058)	0.014 (0.649)	0.035 (1.536)
Number of Managerial Levels	0.261 (0.174)	0.084* (1.660)	0.080 (1.574)	0.032 (0.342)	-0.027 (-0.402)	0.108 (1.455)	0.117* (1.868)	0.026 (0.367)
Proportion workers in self-managed teams	0.177 (0.304)	0.003 (0.096)	0.020 (0.576)	0.052 (0.846)	-0.053 (-1.255)	-0.041 (-0.895)	0.039 (1.001)	-0.038 (-0.926)

Profit sharing	0.567 (0.496)	0.034* (1.890)	0.026 (1.225)	-0.003 (-0.080)	0.065** (2.377)	0.017 (0.559)	0.025 (0.989)	0.027 (0.983)
Employee Voice								
Unionized	0.319 (0.466)	0.098** (4.708)	0.048 (1.241)	0.068 (0.955)	0.097* (1.943)	0.070 (1.263)	0.066 (1.402)	-0.066 (-1.318)
Proportion Workers meeting regularly in Groups	0.539 (0.424)	0.011 (0.507)	-0.027 (-0.958)	-0.062 (-1.145)	-0.045 (-1.190)	-0.036 (-0.817)	-0.040 (-1.138)	-0.040 (-1.040)
Recruitment Strategies								
Grades a top priority in recruitment	0.168 (0.374)	-0.011 (-0.438)	-0.008 (-0.334)	0.005 (0.120)	0.012 (0.414)	-0.011 (-0.337)	-0.007 (-0.250)	-0.025 (-0.850)
Comm. a top priority in recruitment	0.509 (0.500)	0.034* (1.850)	0.032* (1.760)	-0.015 (-0.463)	0.008 (0.356)	0.014 (0.550)	0.022 (1.019)	0.015 (0.667)
Interaction Terms								
Union*profit sharing	0.201 (0.401)		0.029 (0.757)	0.075 (1.155)	-0.017 (-0.368)	0.000 (0.006)	0.007 (0.172)	0.097** (2.076)
Union*re-engineering	0.137 (0.344)		-0.029 (-0.767)	-0.078 (-1.201)	-0.031 (-0.671)	-0.020 (-0.392)	-0.011 (-0.263)	-0.010 (-0.223)
Union*%meet	0.161 (0.331)		0.101** (2.245)	0.108 (1.373)	0.059 (1.069)	0.056 (0.913)	0.124** (2.408)	0.132** (2.364)
%meet*re-engineering	0.226 (0.380)		0.022 (0.523)	0.047 (0.621)	0.109** (2.068)	0.096 (1.599)	0.089* (1.817)	0.052 (0.980)
Union*% in self-managed teams	0.456 (1.579)		-0.007 (-0.988)	-0.014 (-1.063)	-0.003 (-0.321)	-0.003 (-0.356)	-0.005 (-0.712)	-0.003 (-0.308)
N =	637	637	637	439	488	474	557	523
Adjusted R^2 =		0.518	0.499	0.153	0.281	0.247	0.460	0.192

Estimated equations also include a constant term, 2-digit SIC industry controls, establishment size, and a dummy if the establishment is part of a multi-establishment fir
** denotes significance at the 5% level and * denotes significance at the 10% level.
In regressions done by occupation, we also include the percentage of establishment workforce in that occupation.

Table 4: Wage Equation Fixed Effects Model (1996-1993)
T-statistic in parenthesis

Variable	Mean (s.d.)	All Workers	All Workers	Managers	Supervisors	Technical Workers	Production Workers	Clerical Workers
Dependent variable: ln (avg. wage)								
Technology								
Proportion Non-Managers using Computers	0.363 (0.327)	0.027 0.747	0.036 0.967	-0.011 -0.157	0.043 0.929	-0.081 -1.197	-0.036 -0.840	-0.018 -0.331
Worker Characteristics								
Avg. Education	12.5 (0.009)	.054** 3.620	.059** 3.962	.048** 3.171	-0.010 -1.147	.04** 3.423	0.002 0.115	.047** 3.559
Prop. of Employees Trained (within occupation)				0.09* 1.774	0.03 0.745	0.013 0.285	-0.015 -0.553	0.06* 1.752
Turnover (proportion less < 1 yr.)	0.124 (0.134)	-0.029 -0.408	-0.018 -0.250	0.188 1.362	0.084 0.877	0.001 0.011	-0.062 -0.658	-0.004 -0.037
Proportion employees Women	0.346 (0.213)	0.158 1.456	0.68 1.534	0.288 1.507	-0.033 -0.246	0.370** 1.945	0.089 0.689	0.097 0.651
Proportion employees Minority	0.275 (0.252)	-0.161** -2.106	-0.160* -1.866	-0.114 -0.672	0.130 1.049	-0.030 -0.162	-0.231* -2.126	-0.215 -1.613
Use of High Performance Work Systems								
Re-engineering	0.420 (0.495)	-0.006 -0.308	0.068* 1.711	0.067 1.004	0.076* 1.653	-0.087 -1.401	0.044 1.039	0.064 1.277
Benchmarking	0.400 (0.491)	-0.024 -1.152	-0.019 -0.934	0.002 0.045	-0.002 -0.089	-0.025 -0.688	-0.005 -0.222	-0.039 -1.430
Number of Managerial Levels	0.268 (0.193)	0.002 0.411	0.001 0.252	0.001 0.127	0.0001 0.006	-0.001 -0.070	-0.002 -0.245	-0.006 -0.700
Proportion workers in self-managed teams	0.179 (0.311)	0.051 1.405	0.064* 1.620	-0.091 -1.305	-0.046 -0.932	-0.096 -1.251	0.036 0.767	0.126** 2.339
Profit sharing	0.580 (0.495)	0.008 0.359	-0.003 -0.109	-0.016 -0.326	-0.014 -0.406	-0.050 -1.072	-0.013 -0.410	-0.073* -1.884
Employee Voice								

Unionized	0.344	0.076	-.008	0.056	0.026	0.022	-0.085	0.253*
	(0.476)	0.898	-0.081	0.294	0.216	0.121	-0.733	1.655
Proportion Workers meeting regularly in Groups	0.589	0.015	0.002	-0.012	0.054	0.063	0.049	0.097**
	(0.435)	0.611	0.064	-0.196	1.296	1.044	1.212	1.986
Interaction Terms								
Union*profit sharing	0.200		0.042	0.091	0.044	0.155*	0.012	0.042
	(0.401)		0.919	1.082	0.744	1.723	0.222	0.648
Union*re-engineering	0.148		-0.018	-0.038	-0.014	0.078	-0.009	0.089
	(0.356)		-0.441	-0.545	-0.280	1.133	-0.193	1.609
Union*%meet	0.186		0.114**	0.273**	0.062	-0.090	-0.021	-0.019
	(0.358)		2.077	2.698	0.843	-0.892	-0.322	-0.229
%meet*re-engineering	0.268		-0.105**	-0.085	-0.077	0.055	-0.107**	-0.059
	(0.417)		-2.249	-1.081	-1.383	0.710	-2.046	-0.955
Union*% in self-managed teams	0.397		-0.066	-0.048	0.051	-0.042	0.032	-0.198*
	(1.360)		-0.699	-0.305	0.402	-0.240	0.274	-1.579
N =	250	250	250	205	207	183	240	225
Adjusted R^2 =		0.814	0.817	0.511	0.706	0.539	0.773	0.548

Estimated equations also include a constant term, establishment size, and in regressions done by occupation, we also include the percentage of establishment workforce in that occupation.
** denotes significance at the 5% level.
* denotes significance at the 10% level.

Table 5: Compound Average Annual Rates of Growth in Output and the Contribution of Factor Inputs and Multifactor Productivity, Manufacturing (percent per year)

	BLS					EQW-NES
	1949-98	1979-90	1990-95	1995-98	1993-96	1993-96
Output	3.3	2.0	3.8	4.9	4.2	4.7
Combined Inputs[1] (includes capital, labor, materials)	2.1	0.8	2.1	2.3	2.3	3.2
Multifactor Productivity[1,2]	1.1	1.7	2.5	1.9	1.6	
Contribution of R&D[2]	0.2	0.2	0.2	0.2	-	-
Contribution of Workplace Practices[3]	-		-	-	-	1.4
Remaining Residual	-		-	-	-	0.2

Source: Bureau of Labor Statistics, Multifactor Productivity Trends, 1998, released September 21, 2000 and authors' own calculations from the EQW-NES first and second round cross sections with a 1% trim.

1. The growth rate of each input is weighted by its share of nominal costs in the BLS figures and by the estimated coefficient in Table 2 equation 3 for the EQW-NES figures.
2. This is the contribution of R&D to multifactor productivity in private nonfarm businesses, not just manufacturing.
3. This calculation is based on the change in workplace practices and worker characteristics reported in the 1993 and 1996 EQW-NES cross sections weighted by the coefficients on workplace practices and worker characteristics presented in Table 2, equation 3.