

WHAT'S DRIVING THE NEW ECONOMY?: THE BENEFITS OF WORKPLACE INNOVATION*

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This paper argues that changes in workplace organisation, including re-engineering, teams, incentive pay and employee voice, have been a significant component of the turnaround in productivity growth in the US during the 1990s. Our work goes beyond measuring the impact of computers on productivity and finds that these types of workplace innovation appear to explain a large part of the movement in multi-factor productivity in the US over the period 1993–6. These results suggest additional dimensions to the recent productivity growth in the US that may well have implications for productivity growth potential in Europe.

In spite of recent accounting scandals in the US that have cast suspicion on the actual financial performance of an increasing number of firms, the productivity numbers still suggest that from the latter half of the 1990s to the first quarter of 2003 something 'new' was occurring in the US economy. From 1960 until the 1973 oil shock, average annual productivity growth, as measured by output per hour, grew approximately 3% per year for US non-financial corporations. This growth rate then declined to around 1.7% per year from 1973–95. However, since 1995, average annual labour productivity growth for non-financial corporations has risen back up to around 3%. Additionally, US manufacturing productivity grew even faster at almost 4.4% annually during the second half of the 1990s. One consequence of this turnaround in productivity in the US, as detailed in Scarpetta *et al.* (2000), is that the convergence towards the US standard that we observed in manufacturing productivity across industrialised countries from 1960–80 has stopped or even reversed for countries such as the UK, Canada and Germany.

This resurgence of productivity growth has led many to argue that a 'New Economy' has been created in the US. This 'New Economy' is characterised in part by firms increasing their capital investments, especially in information-technology software and hardware. In addition, as we present in this paper, more firms have adopted work processes in which an increasing proportion of non-managerial workers are involved in problem solving and identifying opportunities for innovation and growth. Increased managerial focus on quality management,

* This research was supported in part by the National Science Foundation Program on Innovation and Organizational Change under Grant number 9975878. The authors would like to thank Anya Krivelyova for excellent research assistance. This paper has benefited from comments by Fabio Schiantarelli, Dan Sichel, Kevin Stiroh and participants in seminars at Princeton University, Harvard University, MIT, the NBER, the Institute of Fiscal Studies, the Board of Governors of the Federal Reserve Bank and three anonymous referees. The research in this paper was conducted while the authors were Census Bureau Research Associates at the Boston Research Data Center. Research results and conclusions expressed are those of the authors and do not necessarily indicate concurrence by the Bureau of the Census, the National Science Foundation, the National Bureau of Economic Research, the Federal Reserve Bank of New York the Federal Reserve System. This paper has been screened to ensure that no confidential data are revealed.

continuous innovation, incentive based compensation and employee involvement programmes has in turn raised the productive capacity of the US economy.

Until recently, there has been limited causal evidence on the role of technology and workplace innovation in generating rising productivity in the US during the 1990s. There has also been significant controversy over the extent to which investments in information technology actually contributed to the so-called productivity miracle in the US in the 1990s. For example, Gordon (2003) argues that the role of computers for the late 1990s boom is the US was greatly exaggerated. However, Oliner and Sichel (2002) conclude that in spite of the financial collapse of the high tech sector, the link between IT and productivity remains. They present evidence that the acceleration in labour productivity in the US during second half of the 1990s was driven by both the greater use of IT goods and efficiency gains in the production of IT goods.

In spite of this debate about the relative importance of IT, there does seem to be some agreement that IT does not explain the entire US productivity story. Gordon (2003) argues that early estimates of the contribution of IT investment on productivity were biased upwards for a variety of reasons that included unrealistic assumptions about the speed at which computers affect productivity, micro level evidence that productivity growth in the US retail sector has been driven by other factors, and a comparative analysis of the retail sector in the US and Europe where businesses use the same information technology but still having large differences in productivity growth. Studies by Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) have attempted to decompose labour 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 labour and capital inputs). They find that slightly more than 50% of the growth in output in the US during the 1990s in private non-farm businesses can be explained by multifactor productivity growth. As shown in Figure 1, when one looks only at the manufacturing sector, multifactor productivity growth was an extremely important component of output growth during the 1990s. Therefore, getting a better understanding of what factors might be driving multifactor productivity growth would be an important step forward in understanding what is driving the 'New Economy'. In addition, the nature of these factors will influence the degree of optimism one may have about the long run sustainability of the New Economy in the US and the ability of other countries to replicate such productivity growth.

We use a unique sample of US businesses over the period 1993–6 to examine the role of information technologies (computers) and other capital investment, workplace innovation (including team-work, employee involvement in decision-making and re-engineering activities, and profit sharing) and worker characteristics (education, turnover, gender and race) on productivity. We match plant level practices with plant level productivity and estimate production functions using both cross sectional and longitudinal data. The existence of panel data allows us to control for unobserved time invariant establishment characteristics although it does not control for time-varying unobserved heterogeneity. Ideally we would have preferred to examine a longer time period; however, one advantage of examining

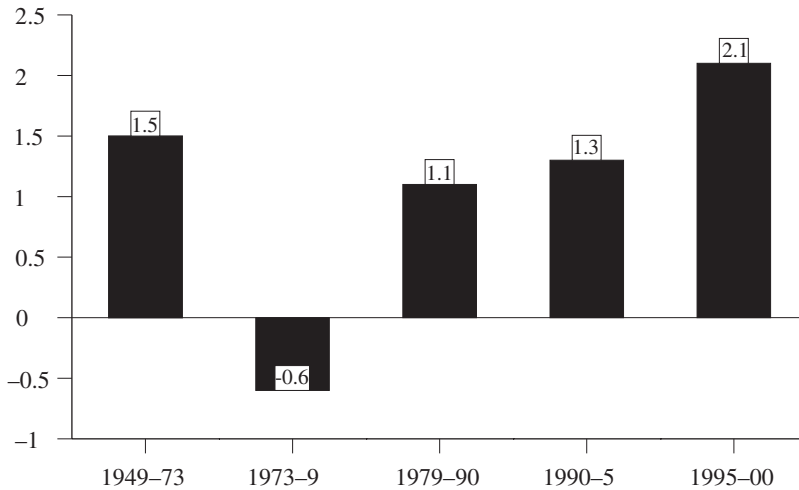


Fig. 1. *Trends in Multifactor Productivity for US Manufacturing* (Average Annual Rates in %)
 Source: US Bureau of Labor Statistics: *Multifactor Productivity Trends in Manufacturing, 2000*, news release date August 29, 2002. <http://www.bls.gov/news.release/prod5.nr0.htm>

this specific period of time is that it covers the turning or inflection point in labour productivity observed in the aggregate US data.

Consistent with our earlier work (Black and Lynch, 1996, 2001), we find that high performance practices are related to 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 unionised establishments. These results suggest that changes in workplace organisation may explain a significant portion of trends in US productivity growth that have been attributed to the New Economy.

1. Background Discussion

Before we discuss how changes in workplace practices are associated with changes in labour productivity, we must first detail our proxies for workplace innovation. As with other intangible assets, there is no consensus definition of what are the best measures of workplace innovation.¹ However, as shown in Figure 2, we see that many employers, interviewed in a 1996 nationally representative sample of US establishments, use a variety of workplace practices that have been often labelled

¹ For a more detailed discussion, see Black and Lynch (2003).

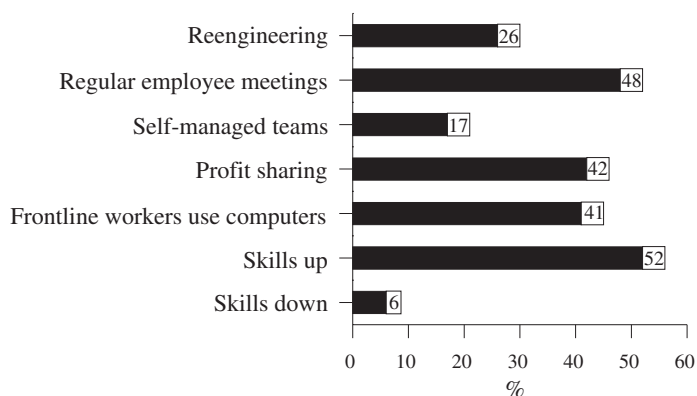


Fig. 2. *Incidence of Workplace Practice*

Source: EQW 2nd Round Survey. Weighted data on US establishment practices in 1996.

Definitions: Re-engineering – any re-engineering 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

‘high performance workplace practices’. Consistent with aggregate data on business investment in information technology, we see that over 40% of US employers reported that three quarters or more of their production workers or frontline employees used computers in their job. However, there is considerable workplace innovation beyond the use of computers by non-managerial workers. For example, in 1996 almost half of all US employers reported that three quarters or more of their employees were involved in regular meetings to discuss workplace issues. In addition, over 40% of employers had some form of profit sharing or stock option plan for employees and 17% of employers reported that a quarter or more of their employees worked in self-managed teams. During the 1990s, many employers revamped their organisational design; we find that more than a quarter reported that they undertook significant re-engineering efforts over the period 1993–6. Finally, the majority of employers reported that the skills required to perform production or support jobs at an acceptable level had increased over the period 1993–6. Only 6% reported that skill levels had fallen.

While there was a great deal of organisational change that occurred during the period 1993–6, the direction of the changes in organisational practices was not the same for all employers. For example, as shown in Table 1, while 30% of employers changed their usage of profit sharing for employees over the period of 1993–6, much of that was away from profit sharing. The extent of employers’ usage of extensive employee consulting on workplace issues also changed in both directions over this time period. So there is considerable variation in the usage of various workplace practices by US employers and this usage changes over time during the 1990s.

Freeman and Lazear (1995) provide a theoretical framework for understanding the linkage between workplace practices and productivity. While their work focuses

Table 1
Changes in Organisational Structure (1993–6)

	% Increased (Moved into group)	% Decreased (Moved out of group)	% Stayed the same
>25% of workers in self-managed teams	13	7	80
Profit sharing	4	26	70
>75% of workers using computers	11	11	78
>75% of workers meeting regularly in groups	22	12	66

Number of observations = 284.
Source. EQW-NES data.

on the role of works council it can easily be extended 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. Their model shows that there is some socially optimal amount of voice/rent taking and that those firms who maximise their own share of the rents and not total rents will under-provide ‘voice’ to workers. A final implication of their model is that we would expect to see a positive association between workplace innovation and productivity.

There is also a growing theoretical and empirical debate on the existence of synergies in bundles of human resource 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) show 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. Ichniowski *et al.* (1997) present compelling empirical evidence in the US steel industry that systems of practices are more important for productivity than individual practices.

The empirical work presented in this paper is not the first to examine the impact of workplace practices on the productivity of businesses but there have been limitations with this earlier work.² 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.³ Although 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 generalise 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 *et al.* (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

² See Black and Lynch (2001) for a more detailed review of the literature.
³ This includes for example work on auto plants by Krafcik (1988) and Womack *et al.* (1991), apparel plants by Berg *et al.* (1996), and a regional phone company by Batt (1995).

sector and see how they are related to variations in performance.⁴ By examining human resource practices associated with one specific production process it is possible to reduce problems of underlying heterogeneity of production processes greatly. 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 and hourly pay). While these results represent an important contribution to the literature on workplace practices and productivity, it is again not easy to generalise 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 a cross section but also longitudinal) and examine the relationship between workplace practices and broader measures of performance such as productivity or profitability. Though one has less detailed information on specific practices than in the case studies or intra-industry studies, the results are generalisable to a much broader group of establishments. A number of papers have examined this relationship and found a significant correlation between human resource management systems and various measures of business performance, including work on US employers by Ichniowski (1990), Huselid (1995), Huselid and Becker (1996), Italian employers by Cristini *et al.* (2001), French employers by Caroli and Van Reenen (2001) and Japanese employers by Kato and Morishima (2002). But much of this work has been plagued by problems such as low survey response rates and the use of indexes of workplace practices, which lead to ambiguities in interpretation.

In earlier work (Black and Lynch, 1996; 2001) we examined the impact of workplace innovation on labour productivity using cross sectional data from a representative sample of US manufacturing employers in 1993. This survey contained a wealth of information on workplace organisation, information technology and human capital investments of individual employers during 1993. We used these data along with additional longitudinal information on past output, employment and capital investment to estimate the relationship between workplace practices and labour productivity. In both of these studies, we found that workplace practices do matter for labour productivity. However, we found that what was associated with higher 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 labour-management relations within the plant. Establishments with more

⁴ Other examples of intra-industry studies include work by Kelley (1994; 1996) on the machine tool industry and Bailey (1993) and Dunlop and Weil (1996) on the apparel industry.

traditional unionised labour-management relations including little or no direct participation of employees in decision making had substantially lower productivity than unionised plants that had adopted new workplace practices such as incentive-based compensation and greater employee participation in decision making. In addition, these unionised plants performed much better than even non-union plants that had adopted similar high performance workplace practices.⁵

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 1988–93. In addition, although the proportion of managerial workers who use computers had no impact on labour productivity, the greater the proportion of non-managerial workers who use computers, the higher was plant productivity.⁶

While there are strengths and weaknesses associated with all of the above-mentioned empirical research, the primary advantage of the work presented in this paper is that we are able to exploit a rich panel data set from a nationally representative survey of establishments to determine whether the effects of workplace innovation obtained at the firm-specific or industry-specific level hold more generally. Having observations on establishments at two different points in time is crucial because it allows us to control for all 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 minimise the problem of 'births' and 'deaths' of establishments that could limit the generalisability 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. We test for the importance of synergies in human resource management practices, match plant level practices with plant level outcomes and analyse the effects of these practices on objective

⁵ Workers may be more willing to participate in employee involvement programmes 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.

⁶ In work that builds on our earlier research, Cappelli and Neumark (2001), using the same surveys as in this paper, examined the relationship between productivity, wages, and workplace practices. However, they only studied manufacturing establishments which were in existence from 1977–96. They estimated the impact of workplace practices on the change in labour productivity of these establishments over the period 1977–93 and 1977–96. However, any manufacturing establishment that was 'born' after 1977 is excluded from their analysis. They do this to address the problem of omitted variable bias associated with unobserved establishment characteristics but the assumption that no US establishments in 1977 used any high performance practices (e.g., profit sharing, employee participation in decision making, or investments in human capital) is an incorrect characterisation of US employers. In addition, during the 1980s and 1990s many firms opened brand new plants to implement new forms of workplace organisation. To exclude these types of establishments as well from the analysis significantly reduces the generalisability of the results and may bias them against finding any effect of workplace practices on productivity.

measures of productivity by estimating production functions on both cross sectional and longitudinal data.

We are also able to examine the relationship between computers and productivity. Recent work by Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) find that a great deal of the productivity growth in the second half of the 1990s can be explained by information technology.⁷ But computers may have more than just a direct effect on productivity of firms. As discussed in Bresnahan *et al.* (2002), information technologies can also have an important effect on the ability of firms to implement organisational changes such as reorganising 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 organisational change, Bresnahan *et al.* (2002) find evidence for complementarities between technology, organisational changes and skills. Unfortunately their work uses just cross sectional micro data on workplace practices. We are able to examine both computer use and other workplace innovations to see their respective impact on productivity.

Given the detailed time varying information contained in this panel data on workplace practices and technology, we can reduce the classic simultaneity problem that has been highlighted in the context of estimating production functions by a variety of authors, including recently Levinsohn and Petrin (2000), by estimating a fixed effects model. However, even though we have much more information on plant characteristics than is typically available in micro studies of production functions, we may still have a problem with biased parameter estimates if there remains any significant unobserved time varying differences across plants. In addition, the workplace practices themselves may well be endogenous. For example, those establishments that become more productive (and in turn more profitable) for reasons other than changes in workplace practices may decide that they can now afford to introduce new workplace practices. We considered using instrumental variables to address this endogeneity problem but it is extremely difficult, especially at the plant level, to find valid instruments that are both correlated with the choice of workplace organisation and orthogonal to such productivity shocks. However, by incorporating the detailed time varying information on plant level characteristics available to us, along with examining a relatively short period of time, we hope to reduce both the simultaneity and endogeneity problems relative to previous studies.

2. 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 used in the empirical estimation.

⁷ In addition, researchers, such as Brynjolfsson and Hitt (2002), who use 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% more than similar workers who did not work with computers. Doms *et al.* (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 labour productivity on the other hand.

The first round of the Educational Quality of the Workforce (EQW) National Employers Survey was administered by the US 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. The survey represents a unique source of information on how employers recruit workers, organise work, invest in physical capital and utilise 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 Standard Statistical Establishment Listing file, one of the most comprehensive and up-to-date listings of establishments in the US. Although the sampling frame omits establishments with less than 20 employees, it captures establishments that employ approximately three-quarters of all workers in the US.

The response rate in the first round EQW National Employers Survey for manufacturing establishments was 75%. 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% 'completed' survey response rate.

A second survey was administered by the Census Bureau in August 1997.⁸ 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% 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%. 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, and

⁸ For more detailed information on response rates for the EQW-NES II see the following internet address: <http://www.irhe.upenn.edu/cgibin/cat.pl#nes1997>.

the costs of materials. This will reduce the final sample sizes used for analysis in this paper.

3. Empirical 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 estimated impact of workplace practices, technology and worker characteristics on labour productivity in 1996 are similar to those found using the 1993 data; see Black and Lynch (1996, 2001). These equations are of the form:

$$\ln(Y/L)_i = \alpha \ln(K/L)_i + \beta \ln(M/L)_i + \delta' \mathbf{Z}_i + \varepsilon_i \quad (1)$$

and

$$\ln(Y/P)_i = \alpha \ln(K/P)_i + \beta \ln(M/P)_i + \gamma \ln(N/P)_i + \delta' \mathbf{Z}_i + \varepsilon_i \quad (2)$$

where Y is the real total value of shipment and sales, K is the real book value of the capital stock, M is the real cost of materials, ε_i is an error term and δ' is a vector of coefficients on \mathbf{Z}_i which are establishment specific workplace practices and characteristics of employees such as education and turnover. In (1) L is the sum of all workers in the establishment and in (2) we differentiate between the total number of production workers (P) and non-production workers (N).⁹

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 Bartelsman and Gray in 1996 and updated recently with the support of Becker at the Census Bureau, Bartelsman *et al.* (2000). (See the Data Appendix for more details.)¹⁰

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. However, by design, many of the manufacturing establishments in the EQW survey could be matched with

⁹ Note that we are constraining the model here to assume constant returns to scale but we will test this assumption in our empirical work.

¹⁰ Although we deflate total sales by detailed industry price deflators this does not control for product quality differences that may exist at the plant level. As detailed in Melitz (2000) this can result in an additional source of bias. Those plants that produce higher quality goods will appear to be more productive when industry level deflators are used. If those businesses with higher quality goods or more diversified production also use different types of work organisation what we attribute to workplace practices may in fact just reflect unobserved differences in products.

the Census Bureau's Longitudinal Research Database, (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 1,493 observations.¹¹

Table 2 presents the results when we use the 1996 survey and estimate cross section production functions ((1) and (2) above). The results presented in this Table are largely consistent with our earlier work. We find estimated coefficients on capital, labour, and materials that are reasonable and similar to those in our previous work. This carries through when we divide labour into production and non-production workers and use sales/production workers as our dependent variable (Columns 2 and 3).¹²

Also 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 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 labour productivity.

We find that some worker characteristics are related to 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 labour productivity but when we divide labour into production and non-production workers in (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 labour 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 labour 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

¹¹ We were concerned about 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.

¹² The imposition of constant returns to scale is always accepted. Note that standard errors are adjusted for heteroscedasticity.

Table 2
Determinants of Labour Productivity: 1996 Cross Section

Variable	Mean (s.d.)	Column 1 Coefficient (t-statistic)	Column 2 Coefficient (t-statistic)	Column 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)
<i>Technology</i>				
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)
<i>Worker characteristics</i>				
Ln (Average education)	2.54 (0.082)	0.693** (2.90)		
Ln (Avg ed non-production 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)
<i>Use of high performance work systems</i>				
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)
<i>Employee voice</i>				
Unionised	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)
<i>Recruitment strategies</i>				
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)
<i>Interaction terms</i>				
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	1,493	1,493	1,493	1,493
Adjusted R ²		0.645	0.822	0.823

Estimated equations are augmented Cobb-Douglas production functions and also include a constant term, 2-digit SIC industry controls and a dummy if the establishment is part of a multi-establishment firm. Columns 2 and 3 divide workers into production and non-production workers. All equations impose constant returns to scale. Standard errors were adjusted for heteroscedasticity.

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

package have higher productivity. Re-engineering¹³ is significant in some of the specifications but bench-marking appears to have little impact on labour productivity. In terms of the impact of employee voice on labour productivity, we find that unionised 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 column 3 of Table 2 we find that unionised establishments with profit sharing have lower labour productivity while unionised establishments that underwent a re-engineering effort have higher labour productivity. While the profit sharing result is a bit perplexing, the unionisation interaction with re-engineering is consistent with the idea that unions provide the necessary job security to make workplace reorganisation effective.

In an effort to try to distinguish whether or not there are synergies between information technology and workplace structure, we tried interacting the percentage of non-managerial workers using computers with various measures of workplace organisation such as the percentage of workers meeting in groups, profit sharing, the number of managerial levels in the establishment and whether or not the firm has undergone reengineering in the last three years. None, however, were statistically significant. We also tried interacting profit sharing with workplace practices to attempt to determine whether these workplace practices are more effective in the presence of incentive schemes as suggested in Boning *et al.* (2001). Again, however, none of these interactions were statistically significant.

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 (Griliches and Mairesse, 1995) due to unobserved establishment characteristics.¹⁴ With two waves of survey data, we are able to begin to address some of these concerns. Consider the following equation:

$$Y_{it} = \alpha'X_{it} + \delta'Z_{it} + v_i + \varepsilon_{it} \quad (3)$$

where Y is sales per production worker; α' is a vector of coefficients on capital per production worker, materials per production worker, and the number of non-production workers per production worker; δ' is our vector of coefficients on

¹³ Re-engineering is the answer to the survey question 'has the establishment has engaged in a major reorganisation 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 organising work on the 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 organisation of work. When we drop the re-engineering variable from the cross section estimation none of the other reported coefficients changes.

¹⁴ 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.

workplace practices from the EQW-NES survey; v_i is an unobserved time invariant establishment fixed effect; and ε_{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 (3), all firm observed and unobserved time invariant fixed effects drop out and we can remove the bias in estimating the coefficients in vectors α' and δ' 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. As discussed earlier, possible biases will still remain due to unobserved time varying characteristics of the establishment. Unfortunately, it is not possible to determine the direction of the biases on the estimated coefficient if there is simultaneity bias and there are many inputs that may be correlated with the error. However, in the fixed effects model, if there is measurement error this will likely generate a downward bias on the estimated coefficients for workplace practices.

Table 3 presents the results when we use our two waves of the EQW-NES survey to estimate (3) allowing for establishment fixed effects. The dependent variable is the difference in labour 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 2, 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. However, as shown in Table 1, there is considerable movement in workplace practices over this three year period of time and these changes are not all in the same direction.

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 labour productivity and statistically significant. In terms of the impact of worker characteristics on productivity, we find little effect of education on productivity but this is likely due to the fact that the average educational level was virtually unchanged over this period. As in the cross section results, we find that higher worker turnover has a negative impact on labour productivity.

Again, workplace practices do matter. We find that firms that re-engineer their workplaces experience higher labour productivity even after controlling for time invariant fixed effects but now we find no impact of profit sharing and/or stock options on labour productivity. In addition, we find after controlling for fixed effects that increased use of self-managed teams is associated with lower labour productivity.¹⁵ Finally, when we examine interaction effects we find that unionised

¹⁵ 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.

Table 3
Determinants of Labour Productivity: Fixed Effects Model (1996–3)

Variable	Mean (s.d.)	Column 1 Coefficient (t-statistic)	Column 2 Coefficient (t-statistic)	Column 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)
<i>Technology</i>				
Proportion non-managers using computers	0.351 (0.317)	0.296** (2.043)	0.345** (2.442)	0.363** (2.564)
<i>Worker characteristics</i>				
Ln (Average education)	2.52 (0.07)	−0.70 (−1.071)		
Ln (Avg ed non-production 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)
<i>Use of high performance work systems</i>				
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)
<i>Employee voice</i>				
Unionised	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)
<i>Interaction terms</i>				
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	0.043 (0.132)			0.179 (0.543)
N	284	284	284	284
Adjusted R ²		0.673	0.797	0.798

Estimated equations are augmented Cobb-Douglas production functions. Columns 2 and 3 divide workers into production and non-production workers. All equations impose constant returns to scale. Estimated equations also include a constant term. Standard errors were adjusted for heteroscedasticity. **Denotes significance at the 5% level. *Denotes significance at the 10% level.

establishments with a higher proportion of workers meeting regularly in groups to discuss workplace issues are also more productive. In other words, the best performing establishments are those who are both unionised and have adopted greater employee participation in decision making.

At the start of this paper we discussed how important multifactor productivity has been during the 1990s in the US in terms of driving output growth, especially in the manufacturing sector. We can use our estimates of the impact of workplace practices on labour 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 1993–5. We present these calculations in Table 4 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 1993–6 as reported by the BLS for the country as a whole.¹⁶ The BLS reports that output growth in manufacturing grew at a compound average annual growth rate of 4.4% during 1993–6. We find a slightly higher rate of 4.7% using the EQW cross sections over the same period. The BLS reports that combined inputs (capital, labour and materials) grew 2.5% over this period and using the estimated coefficient from Table 2, column 3 as shares we find inputs grew 3.2% in the EQW survey. As a result, multifactor productivity grew 1.8% in the BLS reported figures and 1.6% 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% per year. In other words, workplace practices and re-engineering efforts accounted for approximately 30% of output growth in manufacturing over the period 1993–6, or 89% of multifactor productivity. The number of 1.4% may sound high and we believe that this number should be treated as a rough upper bound since some of our workplace practices such as re-engineering reflect both technological as well as organisational changes. Nevertheless, this accounting exercise suggests that

Table 4
Compound Average Annual Rates of Growth in Output and the Contribution of Factor Inputs and Multifactor Productivity for Manufacturing (% per year)

	BLS				EQW-NES	
	1949–2000	1979–90	1990–5	1995–2000	1993–6	1993–6
<i>Output</i>	3.3	2.0	3.1	4.1	4.4	4.7
<i>Combined Inputs</i> * (includes capital, labour, materials)	2.1	0.9	1.8	2.0	2.5	3.2
<i>Multifactor Productivity</i>	1.2	1.1	1.3	2.1	1.8	1.6
<i>Contribution of Workplace Practices</i> †	–	–	–	–	–	1.4
<i>Remaining Residual</i>	–	–	–	–	–	0.2

Source: Bureau of Labor Statistics, *Multifactor Productivity Trends in Manufacturing, 2000*, released August 29, 2002 and authors’ own calculations from the EQW-NES first and second round cross sections with a 1% trim.

*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 3 column 3 for the EQW-NES figures.

†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 3, column 3.

¹⁶ Bureau of Labor Statistics, *Multifactor Productivity Trends in Manufacturing, 2000*, released August 29, 2002.

understanding workplace innovation may go some way in explaining recent trends in multifactor productivity in the US.

4. Conclusions and Implications

During the period 1993–6 we find that US manufacturing employers have been actively engaged in workplace re-organisation and that these changes in workplace practices, along with increasing diffusion of computers, may well have played a significant role in the recent rise in manufacturing productivity. Workplace innovation, especially when it has occurred in unionised establishments, is positively associated with labour productivity in the US. One explanation for this strong effect in unionised establishments is that workers may be more willing to participate in employee involvement programmes if they feel the union will protect their employment security.

While our work, along with previous intra-industry studies, suggests a strong and positive relationship between workplace practices and productivity, the evidence of the effect of these practices on worker welfare is mixed. Aghion *et al.* (1999) show that the impact of organisational change on wage inequality is theoretically ambiguous, for an economy as a whole and for specific employers. Therefore, the impact of workplace innovation on inequality becomes an empirical question. In Black *et al.* (2003) we find that in US manufacturing workplace innovation does seem to be associated with higher wage inequality within employers. Caroli and Van Reenen (2001) using data on British and French firms present evidence that suggests that workplace innovation may be skilled biased while we find a more mixed picture for US manufacturing that varies by union status of the establishment.

More generally, Gordon (2003) argues that part of the reason we see divergence in productivity growth between Europe and the US is due to much larger variation across countries in Europe in information technology usage. Our work suggests that while this may be part of the explanation for the recent divergence in productivity it may also be useful to examine differences in work organisation practices across Europe to understand productivity differences. For example, Nickell and Van Reenen (2000), argue that the gap in relative productivity performance between Britain and the US reflects not only a weakness of investment in high tech areas but also an inability by British employers to absorb best-practice techniques and methods in wide swathes of the market sector. They conclude that part of this is due to low levels of product market competition and general lack of exposure to best-practices methods and technology.

Nickell and Van Reenen (2000) and Metcalf (2002) also point out that the traditional more adversarial relations between labour and management in Britain often worked against innovation and lowered productivity. However they argue that since the mid 1990s there has been some indication of a major shift in labour management relations in Britain towards establishing joint decision making and problem solving arrangements between labour and management. Our work on US employers suggests that there may be significant productivity benefits associated with such arrangements in conjunction with investments in new information and

communication technology. However, whether or not US and European firms will be able to sustain the benefits from workplace innovation such as employee participation in decision making over the long run remains an open question.

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Data Appendix

The price deflators for shipments were constructed from 5-digit product deflators from BEA using the Bartelsman *et al.* (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% 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% of energy costs for 300 of the industries.

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