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Technology adoption and workers' perceptions of changes in skill requirements and technical complexity: Evidence from the 1996 Workplace and Employee Survey Pilot

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Abstract

This paper is part of a larger program of research using the 1996 Workplace and Employee Survey (WES) pilot data to evaluate the potential of the survey to collect data capable of shedding light on important research questions. We use the data to examine differences in workers' perceptions of changes in the skill requirements and technical complexity of their jobs since they started them, and whether these perceptions vary between technology adopters and non-adopters. We find that for technologies costing in excess of $100 000, workers were more likely to report increases in both skill requirements and technical complexity than workers in establishments that adopted lower cost technologies or none at all in the three years preceding the survey. This finding persists even controlling for worker and establishment characteristics, including such establishment factors as their business strategies, geographic sources of competition, and recent organizational changes.

1 Introduction

There is a growing body of evidence that the technological changes that have characterized the last decades of the twentieth century have been, to some degree, upwardly skill-biased. At the micro level, researchers have documented higher wages for workers who use new technologies, or who work in establishments that recently adopted new technologies. Others have documented a difference in the composition of employment between establishments that recently adopted new technologies and those who have not, the former employing a higher proportion of workers with higher education or in high-skilled occupations. Rather than revisit this literature with the small sample Workplace and Employee Survey (WES) pilot data, we accept these conclusions as given, and examine whether workers' perceptions of changes in the skill requirements and technical complexity of their jobs supports this growing consensus. Specifically, we examine whether workers were more likely to report increased skill requirements or technical complexity if they worked for a recent technology adopter than if they did not. We take advantage of the linked nature of the WES pilot to control for a number of both worker and establishment characteristics, including such establishment factors as elements of their business strategies, geographic sources of competition, and recent organizational changes.

One important disadvantage of using this linked data is that we have only data on currently employed workers within establishments. It is quite possible that workers who remain in their establishment several years after the introduction of new technology were not as adversely affected by the technology as those who left voluntarily or who were laid-off in the wake of change. Though our results seem to suggest that workers perceptions confirm the up-skilling view, we are focusing only on a "survivor" population, and a larger analysis of displaced or otherwise relocated workers might change this result.

2 The Workplace and Employee Survey Pilot

In 1996, Statistics Canada tested the planned longitudinal Workplace and Employee Survey questionnaires and data capture tools in a small sample pilot. One goal of the pilot was to determine the potential of the questionnaires to collect useful data for

analysis of questions of interest to academic researchers and policy makers. A sample of about 1000 establishments and 6 to 7 workers per establishment was planned. Because the sample was small, it was decided not to stratify the sample so that it was nationally representative. Instead, select industry and region combinations were chosen and the sample allocated across establishment size groups within these strata. Table 1 describes these strata.

Table 1: Industry/Province Combinati0ns—Sample Sizes and Estimated Populations

	Establishments		Employment	
	Sample Size	Estimated Population	Sample Size	Estimated Population
Logging and mining, quarries and oil wells—Quebec, Ontario, British Columbia	58	3430	152	68092
Manufacturing: Science-based—Canada	78	4709	243	219135
Manufacturing: Scale-based—Ontario	73	4586	115	349477
Transportation/storage/Wholesale—Manitoba, Saskatchewan, Alberta	71	14352	241	241646
Retail trade and commercial services—Manitoba, Saskatchewan	46	11897	130	235200
Finance and Insurance—Quebec	39	3316	149	118465
Real Estate Operations and Insurance Agents—Ontario	66	12699	162	103375
Business Services—Alberta	42	3251	139	72563
Construction—all regions except Manitoba, Saskatchewan, Alberta	48	34915	36	150594
Communications and other Utilites—Canada	47	503	158	361557
Education and health services—Atlantic Provinces, Quebec	38	100	125	229410
Manufacturing: product-differentiated—Canada	75	1735	148	162939
Other	67	19447	162	307519
Total	748	114940	1960	2619972

The final sample available for analysis was 748 establishments and 1959 workers.[2] The low response rate from workers was not a reflection of their unwillingness to participate in the survey. Statistics Canada did not approach workers directly. Because of the perceived trust relationship between employers and employees, establishments were not obliged to provide employee lists. For those establishments that did, Statistics Canada staff drew a random sample of employees and provided these names, together with contact information, to the establishment for distribution to the selected employees. Employees could then return a signed consent form, either agreeing or disagreeing to participate in the survey. Establishments that did not provide employee lists were given consent packages and instructions for drawing a random sample of employees to whom to distribute the packages. A large part of the shortfall in employee response was due to these establishments being unable to distribute the packages. Of all those employees who received consent forms, about 87 percent agreed to participate. Overall, we have employee data for 552 [check] of the 748 establishments. Our analysis is based on a linked panel of these 552 establishments and 1959 workers.

For the most part, the reference period for the survey was 1995. Exceptions to this included the two questions on changes in skill requirements and technical complexity which refer to the period since the worker started her job.[3] Other exceptions were the questions on technological and organizational change on the employer questionnaire. These questions refer to the three years preceding the survey date in order to get a more accurate picture of recent *changes* in technology and organizational structure.[4]

[2] Due to an oversight, one worker ended up with a zero weight.

[3] Due to an oversight in the survey design, the skill requirements question refers specifically to the period since the worker started her job, while the technical complexity question refers to the period since the worker started with her company. We could have also considered the “technical complexity” question to be an employee-based measure of technological change. But here we wanted to treat it as a second, perhaps narrower and more precise dimension of skill change.

[4] Arguably, a three year window is still too short, since the skill (and other) impacts of technological change could in fact take longer to materialize. However, the pilot survey was a ”one off” survey and so faced problems of recall.

3 Methodology

Skill is a multi-dimensional concept. Recent Canadian evidence confirms that workers perceive changes in different dimensions of skill—such as autonomy, control or the technical specifications of their jobs—to change differently. The WES pilot contained two questions on skill: a global question asking whether skill requirements in general increased, decreased or remained the same, and a more specific question asking whether the technical complexity of a worker's job increased, decreased or remained the same. For this analysis, we look at both dimensions of skill (the general and the specific).[5] Table 2 shows the joint distribution of response to the two skill questions. The WES sample was almost evenly split between workers who reported no change in skill requirements and workers who report an increase. Few (6.5 percent) reported a decrease. The likelihood of reporting increased technical complexity was higher. Virtually no one reported a decrease in technical complexity. We see also that workers interpreted these questions differently—44 percent gave different answers for each.

Table 2: Changes in skill requirements and technical complexity

Change in skill requirements and technical complexity since started working in job (percent of employees)	Technical Complexity Increased	Technical Complexity Remained the same	Technical Complexity Decreased	Sample Proportion
Skill Requirements Increased	32.8	12.5	0.1	45.4
Skill Requirements Remained the same	24.8	22.8	0.4	48.1
Skill Requirements Decreased	5.1	1.4	0.1	6.5
Sample Proportion	60.7	38.7	0.6	100

In the analysis that follows we estimate separate logistic regressions of the (marginal) probabilities that workers report an increase, decrease or no change in either skill requirements or technical complexity. The logistic probabilities have the form:

[5] It could be argued that the general "skill requirements" questions includes the specific "technical complexity" concept so that if workers perceive an increase in technical complexity, they are more likely to report an increase in general skill requirements. We see, however, that a larger proportion report increases in technical complexity than general skill requirements.

$$P(J = j \mid b_j, x, t) = \frac{e^{b_j'(x',t')'}}{\sum_j e^{b_j'(x',t')'}}$$

where j = 0,1,2 corresponding to "no change", increase and decrease, β_j is the column vector of parameters associated with (x', t') for each j, x' is a row vector of worker and establishment characteristics, and t' is a row vector of technology adoption controls. Both are discussed in the following paragraphs. Our goal is to estimate β_j and P_j. To identify the model, we normalize $\beta_0 = 0$. Pj are calculated at the mean values for x.

We are primarily interested in whether workers' perceptions of skill change accord with the growing consensus among analysts that technological change is upwardly skill-biased. To do this we want to estimate the probabilities of reporting an increase, decrease or no change in skill depending on whether workers' establishments recently adopted technology or not. The data on technology adoption come from the establishment questionnaire. In three questions, establishments were asked if they had adopted either 1) a significantly new hardware or software application, 2) some other computer-assisted device (e.g., optical scanners), or 3) some other non-computer-assisted device in the last three years. For each of these questions, information on the three most recent implementations was collected. Among this information was the approximate cost of the adoption, which we used in the analysis to distinguish the technologies.

To anticipate results a little, table 10 in the next section indicates that there was no difference between workers in establishments that adopted technology and those in establishments that did not in the likelihood of reporting skill requirements increased. Here an establishment is said to have adopted technology simply if it responded yes to either of the three questions on technology adoption. However, there was a very large variance in the costs of the technologies (and by extension, we assume, in their significance) ranging from less than $100 to as high as $300 million. We therefore divided technologies into "high cost" and "low cost" groups to determine whether there was a threshold level above which a greater likelihood of reporting skills increased could be detected. Through some experimentation, we settled on $100 000 as the cutoff. The vector t, then, consists of two controls: an indicator = 1 if establishments adopted a technology, and no individual

adoption event was $100 000 or more, and a second indicator = 1 if there was at least one adoption event worth $100 000 or more.[6]

It is obvious that a $100 000 investment in new technology in the smallest establishments is qualitatively different than the same scale of investment in the largest. We therefore interact both technology indicators with a continuous employment level variable. All regressions that include establishment controls, therefore, include both a size shift control, and it's interaction with the two technology indicators.[7]

There is also a considerable amount of data collected on innovations introduced by establishments. Establishments in the goods producing sector were asked if they had introduced a new product or process innovation. Establishments in the services producing sectors were asked if they had introduced a new service or a change in the delivery of an existing service. If any establishment cited a "yes" to either of these questions, we considered them to be "innovators." In all the regressions, we add this innovation control as well as an establishment size interaction. We do this because innovation and technology adoption are both part of the technological change that has characterized the past decades, and it is not always clear which phenomenon commentators are referring to when they discuss the impact of change. While a detailed comparison of the skill impacts of technology adoption v. innovation is beyond the scope of this short paper, we did wish to control for the distinction in the probability estimations.

There are certainly other factors that we expect to influence the likelihood of reporting increased skill requirements or technical complexity. The fact that the skill questions refer to the entire period in the job and with the employer suggests that we need

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[6] We chose the $100 000 cutoff by regressing a constant and two technology indicator variables (below cutoff and equal or above cutoff) on the probability of reporting skill requirements increased, remained the same, or decreased, and incrementing the cutoff in $1000 units starting at $10 000. We saw that a cutoff as low as $20 000 resulted in a greater likelihood of reporting skill requirements increased for employees in "above-or-equal-cutoff" establishments than those who were not. However, once we controlled for other workplace and worker characteristics, the cutoff had to be at least $100 000 for the difference between workers in "above-or-equal-cutoff" establishments and workers not in these establishments in the probability of reporting increased skill requirements to remain significant. Our goal was to determine whether there was some threshold "magnitude" of technology adoption, proxied here by cost, above which an upward skill impact could be detected, controlling for other key variables.

[7] We had also included dichotomous size indicator variables, one for small establishments and one for large establishments and found similar results. In the interest of reducing the number of regressors and for calculating elasticities of probabilities with respect to size, we settled on the continuous indicator.

to control for tenure. Longer tenure workers might be more likely to report a change (be it increase or decrease) simply because they have been in their jobs longer. There is also an initial skill level that every employee would have had at the time a technology was adopted. For any given change in establishments that manifests itself in changed skill requirements (be it technological change or some other market or business environment change), higher skilled workers may be less likely to report an increase in skill requirements because they are already relatively highly skilled. We see empirically that the likelihood of reporting increased skill requirements increases monotonically with establishment size. We also see marked variation in the likelihood of reporting increased skill requirements by industry: an almost two-fold difference between workers in the scale based manufacturing or finance and insurance sectors and the business services sector and an almost three-fold difference between workers in the former two sectors and retail trade. Table 3 shows the changes in skill requirements reported by workers by select worker and establishment characteristics. Table 4 shows the same for changes in technical complexity.

Table 3: change in skill requirements by select worker and workplace characteristics[8]

		Remained the Same	Increased	Decreased	Sample Proportion
Gender	Male	49.5	45.4	5.1	55.2
	Female	46.4	45.4	8.3	44.8
Tenure	Less than 1 year	49.1	38.7	12.2	3.3
	1 to <2 years	56.6	40.5	2.9	20.3
	2 to <5 years	47.6	46.2	6.2	36.5
	5 to <10 years	43.2	49.3	7.5	23.0
	10 or more years	45.4	45.4	9.2	16.9
Education	Less than high school	73.7	25.2	1.1	9.8
	Completed high school	46.2	45.7	8.0	18.4
	Post Secondary Education	44.5	50.2	5.3	48.9
	University	46.3	43.3	10.4	23.0
Select Occupation Major Groups	Managers	33.3	61.1	5.6	28.7
	Professional	58.3	34.6	7.2	15.8
	Clerical	41.2	49.5	9.3	20.2
	Other	59.6	35.0	5.4	35.5
Wage	Less than $10/hr.	69.2	30.7	1.1	16.5
	$10 to $19.99/hr.	44.6	50.0	5.4	44.9
	$20 or more/hr.	43.6	46.3	10.1	38.6
Weekly hours of work	Full-time	44.4	48.5	7.1	90.6
	Part-time	83.5	15.5	1.1	9.4
Establishment Size	0 to 19 employees	68.9	29.6	1.5	16.5
	20 to 99 employees	50.6	42.4	7.0	16.7
	100 to 499 employees	46.4	48.2	5.5	18.8
	500 or more	40.8	50.7	8.5	48.0
WES Industry Group	Forestry	49.4	43.5	7.1	4.0
	Manuf: Scale-based	26.6	66.7	6.7	13.3
	Manuf: Prod-differentiated	56.9	39.4	3.7	6.2
	Manuf: Science-based	43.0	47.0	9.9	8.4
	Construction	63.6	31.5	4.9	5.8
	Transportation	58.0	38.2	3.8	11.1
	Communications	35.3	51.3	13.4	13.8
	Retail Trade	74.9	24.3	0.8	9.0
	Finance and Insurance	26.4	66.5	7.1	9.2
	Real Estate	57.6	35.7	6.7	4.0
	Business Services	62.5	35.4	2.1	6.6
	Education and Health Services	56.6	36.6	6.8	8.8
Sample Proportion		48.1	45.4	6.5	

We can summarize the relative differences in changes in skill requirements as follows:

* Women were more likely than men to report a decrease;
* Beyond one year tenure, longer tenure workers were more likely than shorter tenure workers to report a decrease. Up to ten years tenure, longer tenure workers were more likely to report an increase;

[8] Rows – sample proportion add to 100.

* The least educated were more likely than the higher-educated to report no change; University graduates were twice as likely as other post-secondary graduates to report a decrease. Other post-secondary graduates were more likely than other educational groups to report an increase;
* The lowest-wage workers were most likely to report no change. The probability of reporting a decrease seems to increase monotonically with wage;
* Part-time workers were much more likely than full-time workers to report no change;
* Professional and other occupations were more likely than managers and clerical workers to report no change. Managers were more likely to report an increase. Clerical workers were more likely to report a decrease;
* The likelihood of reporting an increase increases with establishment size, but at an apparently decreasing rate. The likelihood of reporting no change decreases with establishment size;
* And, workers in retail trade were considerably more likely to report no change. Workers in scale-based manufacturing and the finance and insurance sector were more likely to report an increase. Interestingly, workers in science-based manufacturing and communications were relatively more likely to report decrease.

Table 4: change in technical complexity by select worker and workplace characteristics[9]

		Remained the Same	Increased	Decreased	Sample Proportion
Gender	Male	35.5	64.2	0.4	55.2
	Female	42.6	56.4	1.0	44.8
Tenure	Less than 1 year	44.2	55.3	0.5	3.3
	1 to <2 years	51.1	47.6	1.3	20.3
	2 to <5 years	47.5	52.3	0.3	36.5
	5 to <10 years	27.3	71.5	1.1	23.0
	10 or more years	19.2	80.8	0.0	16.9
Education	Less than high school	61.7	37.4	0.9	9.8
	Completed high school	43.6	56.1	0.3	18.4
	Post Secondary Education	33.4	65.6	1.0	48.9
	University	36.0	63.8	0.2	23.0
Select Occupation Major Groups	Managers	32.5	66.7	0.8	28.7
	Professional	23.3	75.9	0.7	15.6
	Clerical	30.1	69.4	0.5	20.2
	Other	55.3	44.2	0.6	35.5
Wage	Less than $10/hr.	65.3	34.6	0.1	16.5
	$10 to $19.99/hr.	38.4	60.7	0.9	44.9
	$20 or more/hr.	27.7	71.8	0.6	38.6
Weekly hours of work	Full-time	34.9	64.4	0.7	90.6
	Part-time	75.2	24.6	0.2	9.4
Establishment Size	0 to 19 employees	53.3	45.9	0.8	16.5
	20 to 99 employees	31.6	67.9	0.5	16.7
	100 to 499 employees	40.5	58.7	0.8	18.8
	500 or more	35.4	64.1	0.6	48.0
WES Industry Group	Forestry	37.8	62.0	0.2	4.0
	Manuf: Scale-based	25.8	73.5	0.7	13.3
	Manuf: Prod-differentiated	38.3	61.3	1.7	6.2
	Manuf: Science-based	37.0	61.3	1.7	8.4
	Construction	61.7	38.3	0.0	5.8
	Transportation	31.3	67.8	1.0	11.1
	Communications	33.1	66.9	0.0	13.8
	Retail Trade	81.8	18.0	0.2	9.0
	Finance and Insurance	28.0	71.4	0.7	9.2
	Real Estate	40.4	59.3	0.4	4.0
	Business Services	36.1	63.4	0.5	6.6
	Education and Health Services	31.9	68.1	0.0	8.8
Sample Proportion		38.7	60.7	0.6	

We can summarize the relationship between worker and establishment characteristics and changes in technical complexity as follows:

* Men were more likely than women to report an increase;
* Above one year of tenure, the probability of reporting an increase grew monotonically;
* Workers in other than the management, professional and clerical occupations were much less likely to report an increase;
* Higher wage workers were more likely to report an increase;

[9] Rows – sample proportion add to 100.

* Full-time workers were almost three times as likely as part-time workers to report an increase;
* Workers in the smallest establishments (0 – 19 employees) were less likely to report an increase;
* And, workers in finance and insurance and scale-based manufacturing were among the most likely to report an increase. Workers in retail trade were the least likely;

Perhaps the central advantage of the WES is the wealth of data it collects, particularly from establishments. For the first time, we have data on such factors as business strategies, areas of competition, and organizational changes that can be linked with data on employees. Our analysis takes advantage of this data. First, we chose to model elements of business strategies because these might be thought to be reasonable proxies for the overall business environment of the firm.

With respect to business strategies we see that those strategies that could be loosely called “product development strategies”, namely undertaking R&D, developing new products or services, and developing new production or operating techniques tended to be associated more with increased skill requirements and technical complexity (with a few exceptions). Tables 5 and 6 show the responses to the two skill questions by very important or crucial elements of business strategy.

Table 5: Change in skill requirements by very important or crucial business strategies[10]

	Remained the Same	Increased	Decreased	Sample Proportion
Undertaking research and development	38.7	54.8	6.6	40.9
Developing new products/services	39.9	54.7	5.5	47.1
Developing new production/operating techniques	43.2	49.3	7.5	49.4
Expanding into new geographic markets	45.9	46.3	7.8	41.1
Total quality management	44.2	49.9	5.9	54.7
Improving product or service quality	45.2	47.4	7.4	81.4
Reducing labour costs	47.8	44.4	7.8	53.4
Using more part-time temporary or contract workers	48.7	42.5	8.9	15.2
Reducing other operating costs	47.2	46.3	6.5	63.1
Reorganizing the work process	44.0	47.8	8.3	42.6
Enhancing labour management cooperation	44.1	48.9	7.0	52.5
Increasing employees' skills	46.5	47.7	5.9	66.2
Increasing employee involvement/participation	44.3	50.1	5.6	51.8
Improving coordination with customers and suppliers	47.0	46.4	6.6	71.8
Sample Proportion	48.1	45.4	6.5	

Table 6: Change in technical complexity by very important or crucial business strategies[11]

	Remained the Same	Increased	Decreased	Sample Proportion
Undertaking research and development	29.1	70.2	0.7	40.9
Developing new products/services	30.9	68.6	0.5	47.1
Developing new production/operating techniques	31.4	68.1	0.6	49.4
Expanding into new geographic markets	34.9	64.7	0.4	41.1
Total quality management	34.9	64.2	0.9	54.7
Improving product or service quality	37.3	61.3	0.8	81.4
Reducing labour costs	41.5	58.2	0.4	53.4
Using more part-time temporary or contract workers	55.9	43.9	0.3	15.2
Reducing other operating costs	40.8	58.8	0.4	63.1
Reorganizing the work process	32.0	67.3	0.7	42.6
Enhancing labour management cooperation	35.3	64.4	0.3	52.5
Increasing employees' skills	39.5	59.9	0.7	66.2
Increasing employee involvement/participation	35.2	64.1	0.7	51.8
Improving coordination with customers and suppliers	39.3	60.2	0.6	71.8
Sample Proportion	48.1	45.4	6.5	

For the purposes of analysis we identify one indicator variable = 1 if the establishment considered doing R&D, developing new products or services, or developing new production and operating techniques was very important or crucial. We label this group the "product development" strategy group.[12] The omitted group includes those establishments that report these elements are "important" or "slightly important".

We consider organizational change controls based on the growing evidence that the impacts of technological change are likely to be either more intense or felt more readily

[10] Rows – sample proportion add to 100.
[11] Rows – sample proportion add to 100.
[12] This is not to be confused with Drolet (forthcoming) who uses a didfferent definition of product development strategies.

if there is concomitant organizational changes. We see that most workers worked for establishments that reported downsizing or engineering were their most significant organizational changes. However, these workers seemed only slightly more likely to report increased skill requirements than workers in establishments that reported other changes. Workers in establishments that recently downsized were more likely to report decreased skill requirements and workers in establishments that made no change were more likely to report no change in skill requirements. The case for technical complexity and organizational change was somewhat different. Workers in establishments that either downsized or reengineered were little more likely to report increased skill requirements than workers in establishments undertaking other changes, with the notable exception of of workers in establishments putting greater reliance on temporary or part-time workers. Workers in establishments that made no change were more likely to report no change in technical complexity. Tables 7 and 8 show the responses to these two questions by most significant organizational changes.

Table 7: Change in skill requirements by organizational changes[13]

	Remained the Same	Increased	Decreased	Sample Proportion
Any of 13 organizational changes (question 19)				
No organizational change	64.0	34.4	1.6	9.9
Downsizing	43.3	47.9	8.8	57.4
Reengineering	44.8	47.6	7.6	72.6
Increased integration among different functional areas	42.2	50.3	7.5	58.3
Increase in the degree of centralization	35.0	56.9	8.0	27.7
Decrease in the degree of centralization	42.7	51.4	5.9	27.1
Greater reliance on temporary workers	38.4	55.0	6.6	25.1
Greater reliance on part-time workers	51.2	45.7	3.1	28.2
Increase in overtime hours	45.3	49.6	5.1	38.7
Adoption of flexible working hours	44.7	47.5	7.8	32.4
Delayering	43.8	49.6	6.6	42.2
Greater reliance on functional flexibility	44.5	50.5	5.0	56.3
Increased reliance on external suppliers of products/services	47.0	47.1	6.0	40.8
Increased inter-firm collaboration in R&D	42.7	51.5	5.8	37.0
Most Significant Organizational Change (question 20)				
Downsizing	39.8	47.7	12.4	32.7
Reengineering	45.7	49.4	5.0	26.9
Increased integration among different functional areas	47.5	43.9	8.6	4.5
Increase in the degree of centralization	40.6	53.8	5.6	1.5
Decrease in the degree of centralization	51.6	45.8	2.7	1.1
Greater reliance on temporary workers	43.0	26.7	30.3	0.7
Greater reliance on part-time workers	80.5	19.5	0.0	7.2
Increase in overtime hours	37.2	61.5	1.3	5.5
Adoption of flexible working hours	67.8	23.6	8.6	0.4
Delayering	36.6	63.5	0.0	0.3
Greater reliance on functional flexibility	50.3	47.8	2.0	5.2
Increased reliance on external suppliers of products/services	48.7	51.2	0.1	2.5
Increased inter-firm collaboration in R&D	48.4	47.7	3.9	1.7
Sample Proportion	48.1	45.4	6.5	

[13] Rows – sample proportion add to 100.

Table 8: Change in technical complexity by organizational changes[14]

	Remained the Same	Increased	Decreased	Sample Proportion
Any of 13 organizational changes (question 19)				
No organizational change	58.3	40.7	1.1	9.9
Downsizing	37.8	61.5	0.7	57.4
Reengineering	34.9	64.5	0.6	72.6
Increased integration among different functional areas	30.6	68.6	0.8	58.3
Increase in the degree of centralization	24.8	74.1	1.1	27.7
Decrease in the degree of centralization	32.9	66.5	0.7	27.1
Greater reliance on temporary workers	33.7	66.2	0.2	25.1
Greater reliance on part-time workers	44.0	55.9	0.2	28.2
Increase in overtime hours	38.9	60.6	0.5	38.7
Adoption of flexible working hours	27.7	71.9	0.4	32.4
Delayering	37.6	61.5	0.9	42.2
Greater reliance on functional flexibility	37.6	61.7	0.7	56.3
Increased reliance on external suppliers of products/services	43.2	56.1	0.7	40.8
Increased inter-firm collaboration in R&D	31.4	68.0	0.7	37.0
Most Significant Organizational Change (question 20)				
Downsizing	31.2	68.5	0.4	32.7
Reengineering	31.3	67.7	1.0	26.9
Increased integration among different functional areas	29.7	68.9	1.3	4.5
Increase in the degree of centralization	30.4	69.6	0.0	1.5
Decrease in the degree of centralization	32.0	68.0	0.0	1.1
Greater reliance on temporary workers	74.4	21.8	3.8	0.7
Greater reliance on part-time workers	83.6	16.4	0.0	7.2
Increase in overtime hours	22.6	77.4	0.0	5.5
Adoption of flexible working hours	22.9	77.1	0.0	0.4
Delayering	33.1	62.4	4.5	0.3
Greater reliance on functional flexibility	43.6	55.6	0.8	5.2
Increased reliance on external suppliers of products/services	50.7	49.2	0.1	2.5
Increased inter-firm collaboration in R&D	33.1	60.1	0.9	1.7
Sample Proportion	38.7	60.7	0.6	

On the basis of the sample distribution we define three indicators: one = 1 if the establishment downsized in the past three years, another = 1 if the establishment reengineered, and finally, an indicator = 1 if the establishment made no organizational change in the past three years. We omit the category "other significant organizational change".[15]

Lastly, we consider controls for "globalization" under the hypothesis that skill impacts of technological change may not be separable, but entangled in a large range of

[14] Rows – sample proportion add to 100.

[15] We examine "most significant" organizational changes rather than the "multiple response" question to avoid arbitrary groupings of organizational changes. In estimates not reported here, we grouped the changes reported in the multiple-response question into "numeric" and "functional" changes, loosely following a recent OECD taxonomy. We also used groupings based on cluster analysis conducted for a previous paper (Ekos, 1998). The many ways the organizational change data from the WES could be analyzed makes a detailed discussion of organizational change and skill requirements beyond the scope of this paper. At this stage, we want to control for those changes employees seem most exposed to.

impacts following changes in global markets and competition. We defined two indicator variables: one = 1 if the establishment reports that competition from international sources (other than the U.S.) is very important or crucial, another = 1 if establishments report the same for U.S. sources and not other international sources. Note that these definitions are hierarchical. Establishments that report very important or crucial competition from international sources (other than the U.S.) are labeled "international competitors" regardless of whether or not they face the same degree of competition from U.S., national, or sub-national sources as well. We do the same for those reporting very important or crucial competition from U.S. but not international sources. As in the case of business strategy elements, the omitted group is somewhat messy. It includes not only establishments facing very important or crucial competition at the national or local level and not higher, but also those reporting "important" or "slightly important" competition at the U.S. or international level.[16]

Table x summarizes the definition of the worker, establishment and technology controls, and shows the sample means and standard deviations. Recall that this analysis is based on a linked worker file. Means refer to the proportion of workers in establishments with a certain characteristic and *not* the proportion of establishments with that characteristic.

[16] In a reworked version of this analysis, we plan to include controls for cases where "product development strategies" are "important" or "slightly important" and where U.S. and Foreign competitors are "important" or "slightly important" to make the omitted group more distinct.

Table 9: Definition of worker, and establishment characteristics used in regressions

Variable	Definition	Mean	Std. Dev
Worker controls			
FEMALE	=1 if woman	44.77	18.19
TENURE	Weeks since started job	300.50	10335.95
WAGE	Wage per hour earned on job	19.80	458.29
PART	=1 if part-time (<30 hrs. per week)	0.09	10.69
PSE	=1 if post-secondary, non-university	0.49	18.29
UNIV	=1 if completed university	0.23	15.39
MANAGE	=1 if manager (SOC2 group 11)	0.29	16.55
CLER	=1 if clerical (SOC2 group 41)	0.20	14.70
PROF	=1 if professional (SOC2 groups 21, 23, 25, 27, 31, 33)	0.16	13.26
Establishment controls[17]			
Q1A	Establishment employment (number of workers)	2566.90	210064.61
FOREST	=1 if in forestry group	0.04	7.13
SCALE	=1 if in scale-based manufacturing group	0.13	12.44
PRDIFF	=1 if in product-differentiated manufacturing group	0.06	8.834
SCIENCE	=1 if in science-based manufacturing group	0.08	10.13
COMM	=1 if in communications group	0.14	12.62
CONST	=1 if in construction group	0.06	8.51
TRANS	=1 if in transportation group	0.11	11.48
BISERV	=1 if in business services group	0.07	9.07
RESTATE	=1 if in real estate group	0.04	7.12
FINANCE	=1 if in finance	0.09	10.59
HTHED	=1 if in health or education group	0.09	10.34
Augmented establishment controls			
PRDEV1	=1 if either of 1st , 2nd or 3rd business strategy is very important or crucial	0.34	17.38
DOWN	=1 if most significant organizational change is downsizing	0.32	17.17
REENG	=1 if most significant organizational change is reengineering	0.27	16.22
NOCHNG	=1 if there was no significant organizational change	0.10	10.95
USCOMP	=1 if establishment faces very important or crucial competition from US	0.18	13.89
INCOMP	=1 if establishment faces very important or crucial competition from other int'l firms	0.10	11.12
Technology and innovation covariates			
TECH2	=1 if adopted technology < $100 000	0.35	17.43
TECH3	=1 if adopted technology >= $100 000	0.34	17.27
Q1ATECH2	Q1A x TECH3	1673.08	210973.39
Q1ATECH3	Q1A x TECH2	421.86	43856.66
INNOV	=1 if introduced an innovation	0.55	18.22
Q1AINNOV	Q1A x INNOV	2083.99	211170.65

For each of the two sill questions, we estimate three regressions, one using only worker characteristics and the technology dummies with *no* establishment size interaction terms and no innovation or innovation/size interaction term. In a second regression we add establishment size and industry group controls, including size interactions, and in a third we add to these the "augmented" controls for strategies, competition and organizational change discussed above.

4 Results

[17] See table 1 for definition of industry/region.groups

As indicated in the previous section, there was no difference between employees of technology adopters and employees of non-adopters in the likelihood of reporting increased skill requirements (table 10). There was, however, considerable difference between employees of the two kinds of adopters in their likelihood of reporting increased skill requirements. Employees in the "expensive" adopters were about two times as likely as employees in other technology adopters to report an increase. Interestingly, there was less relative difference between employees of these two kinds of establishments in their likelihood of reporting decreased skill requirements. But there were notable differences between workers in non-adopters high-cost adopters in their probabilities of reporting a decrease. On the whole, for at least a subset of technology adopters, their employees perceived an increase in skill requirements.

Table 10: Change in skill requirements by establishment technology adoption

	Remained the Same	Increased	Decreased	Sample Proportion
Establishment adopted technology	47.4	45.4	7.3	68.4
Establishment adopted technology 0 - $99 999	57.3	27.7	6.7	34.9
Establishment adopted technology >= $100 000	37.1	55.1	7.8	33.6
Establishment did not adopt technology	49.6	45.4	5.0	31.6
Sample proportion	48.1	45.4	6.5	

The case for technical complexity is similar (Table 11). We found little difference between workers in technology adopters and non-adopters in the probability of reporting increased technical complexity. However, those workers in establishments that recently adopted expensive technology were considerably more likely than workers in non-adopters to report increased technical complexity. They were also more likely to report increased technical complexity than workers in establishments that adopted less expensive technologies.

Table 11: Change in technical complexity by establishment technology adoption

	Remained the Same	Increased	Decreased	Sample Proportion
Establishment adopted technology	37.2	62.2	0.6	68.4
Establishment adopted technology 0 - $99 999	45.3	54.2	0.5	34.9
Establishment adopted technology >= $100 000	28.8	70.4	0.8	33.6
Establishment did not adopt technology	41.3	57.5	0.7	31.6
Sample proportion	38.7	60.7	0.6	

The next set of tables reports the estimated probabilities discussed in the previous section controlling for worker, establishment, and "augmented" establishment characteristics. Parameter estimates for all models are provided in appendix tables.

For workers in establishments that did not adopt technology, we see an increasing likelihood of reporting no change in skill requirements as we add controls. We also see that adding establishment controls reduces the likelihood of reporting decreased skill requirements among both adopters and non-adopters. Controlling just for worker characteristics, however, leaves some appreciable difference in reporting decreased skill requirements: workers in "expensive" technology adopters were more likely than workers in "low cost" adopters and non-adopters to report decreases. Thus, we tentatively conclude that the relatively higher likelihood of reporting decreased skill requirements among workers in technology adopters is an artifact of establishment size or industry.

We see in all cases that workers in the "high cost" adopters were more likely than workers in the "low cost" and non-adopting establishments to report increased skill requirements. In fact, workers in non-adopters were more likely than workers in low cost adopters to report increased skill requirements. This difference disappears as more controls are added. We note also that adding controls as we have results in greater probabilities that workers in both high and low cost technology adopters report increased skill requirements than those suggested by the sample proportions. Controlling for establishment characteristics particularly increases the likelihood that workers in low cost adopters also report increased skill requirements. Finally, we notice a considerable reduction in the probabilities that workers in the "high cost" adopters report increased skill requirements when "augmented" establishment controls are added to the standard size and industry controls. Given the many ways these controls could be specified in the regression

analysis, we are hesitant at this stage to conclude that controlling for them reduces the likelihood of increased skill requirements associated with working for high cost adopters. We do make the important observation that when workplace variables, other than the ones traditionally available on household surveys (i.e., firm size and industry) are included, results can change.

Table 12: Estimated probabilities of change in skill requirements controlling for worker and workplace characteristics

	Regression 1: Controlling for Worker characteristics			Regression 2: Controlling for worker and workplace characteristics		
	Remained the same	Increased	Decreased	Remain the same	Increased	Decreased
Did not adopt technology	47.4	48.6	4.0	49.9	49.1	1.0
Adopted technology < $100 000	58.6	36.0	5.4	49.6	48.8	1.5
Adopted technology >= $100 000	37.4	55.7	7.0	35.8	62.3	0.9
Likelihood		-1482.5			-1581.5	
LR test statistic [18](*** = sig at < 1%)					198.1***	

Table 13: Estimated probabilities of change in skill requirements controlling for worker and augmented workplace characteristics

	Remain the same	Increased	Decreased
Did not adopt technology	52.4	46.9	0.8
Adopted technology < $100 000	51.7	46.2	2.2
Adopted technology >= $100 000	39.8	59.6	0.7
Likelihood ratio		-1449.0	
LR test statistic		264.9***	

For technical complexity, we notice little change in the probability workers in non-adopters report no change. We see similar probabilities of reporting no change as those suggested by the sample proportions for technology adopters as we add controls, with the exception of adding "augmented" controls where there is no difference between workers in low cost adopters and non-adopters. As suggested by the sample proportions, there was

[18] The LR statistics show test the hypothesis that the addition of controls to the preceding regression significantly improved the estimated likelihood function.

little likelihood of reporting decreased technical complexity, even controlling for worker and establishment characteristics.

As is the case with skill requirements, we see that adding the usual establishment industry and size controls increases the probability of reporting increased skill requirements for workers in high cost adopters, but that this relatively higher probability decreases once the "augmented" controls are added. Again, we believe this underlines the importance of controlling more accurately for other establishment characteristics. Overall, we see somewhat similar rates of reporting increased technical complexity as suggested by the sample proportions among workers in technology adopters, even the low-cost adopters, controlling for establishment and worker characteristics.

Table 14: Estimated probabilities of change in technical complexity controlling for worker and workplace characteristics

	Regression 1: Controlling for Worker characteristics			Regression 2: Controlling for worker and workplace characteristics		
	Remained the same	Increased	Decreased	Remain the same	Increased	Decreased
Did not adopt technology	38.7	61.0	0.3	37.1	62.7	0.2
Adopted technology < $100 000	46.3	53.4	0.3	44.0	55.8	0.2
Adopted technology >= $100 000	29.8	70.0	0.2	25.9	75.0	0.1
Likelihood		-1103.9			-1171.0	
LR test statistic (*** = sig at <1%)					136.1***	

Table 15: Estimated probabilities of change in technical complexity controlling for worker and augmented workplace characteristics

	Remain the same	Increased	Decreased
Did not adopt technology	40.0	60.0	0.0
Adopted technology < $100 000	40.0	60.0	0.0
Adopted technology >= $100 000	29.2	70.7	0.0
Likelihood ratio test statistic		-1092.2	
LR test statistic		157.6***	

5 Discussion and Considerations for Future Work

This paper was part of a larger research exercise intended to evaluate the potential for WES data to address issues of current concern. We take as given the growing consensus that technological change has been largely upwardly skill-biased, and examine whether workers' perceptions of changes in the skill requirements and technical complexity of their jobs accords with this consensus. For the most part, we see that it does, *if* one does not treat all incidents of technological change equally. Controlling for a variety of establishment and worker characteristics, we see that at least for workers in establishments that adopted high cost technologies, the probability of reporting skill requirements increased is higher than that suggested by simple sample proportions, and the probability that technical complexity increased is similar. Perhaps importantly, the apparent relatively higher likelihood of reporting decreased skill requirements for workers in establishments that adopted technology v. those whose establishments did not, disappears once size and industry groups are controlled for. Certainly this analysis needs to be complemented by more careful (perhaps more theoretically and objectively based) analysis of the skill impacts of technology—and to revisit studies based on wage premia and employment composition with larger, more representative samples.

As for the WES pilot, we were encouraged to see that controlling for workplace factors hitherto unavailable for the analysis of worker data did alter the results of our analysis. It suggests that these additional employer characteristics need to be carefully modeled (and survey instruments carefully designed to collect meaningful data) to perhaps revisit the evidence on skill-biased technological change.

With particular respect to the controls used in this analysis we had some concerns. First, the competition variables asked only about the degree of importance of competition, and not on what dimension competition takes place. There were some questions on the share of revenues earned by geographic region, percentage of assets held by foreign owners, number of competitors and whether or not the establishment charges a higher, similar, or lower price than its major competitors. Perhaps some combination of data from these questions could provide clearer control for globalization factors. We are not able distinguish between import and export competition.

There is a lot of data available on the range of adoption of certain organizational changes, both in groups and in terms of a singular, most significant change. Regarding the latter, we do have data on objectives, impacts, and factors which contributed positively or negatively to the change, which could be used to focus on certain changes, intended goals, or changes that occurred despite certain barriers.[19] Ideally, however, we should be looking at combinations of change that have taken place. To do this effectively, we should compare our data with other studies using different taxonomies of change.

There is, of course, the central issue of measuring technological change. We already alluded to the wealth of data collected on the technologies adopted by establishments. In addition to the costs, we have data on dates of implementation, number of employees affected, number of employees directly using the technology who were trained to use it, the average duration of that training, and the broad occupation groups that use the technology. We also have data on the impacts, including changes in the employment of management and non-management workers and a question similar to that asked of workers to determine whether establishments believe their workers skill requirements have increased, decreased or remained the same. We also used a simple innovation control in our analysis. We do have data on whether the innovation was a world, national, or local "first" in its market. With a larger sample, we might use this data to better differentiate the technologies, and to distinguish between technology adoption and innovation activity—in some senses the source and "destination" of technological change.. Clearly this is the direction in which research of this nature needs to go.

Apart from this need to explore more carefully some of the employer data, there are, of course, statistical concerns which limit our ability to draw strong conclusions from the pilot data. First, of course, is the small, non-representative sample. Much of what we find may be industry and size specific. We already noted that the relatively higher likelihood of reporting decreased skill requirements for workers in high-cost technology adopters disappears when we control for size and industry group. However, we are really controlling for the industry/region combinations we chose for the pilot. Thus, the

[19] Betcherman and Leckie examine some of the objectives, impacts and contributing factors data in Ekos, 1998.

disappearance of this result might be tempered by more nationally representative data. Another issue is the reference period for different data. The technology questions refer to the last three years, partly to capture some volume of change in a “one shot” survey. This prevents us from meaningfully taking ratios of the costs of technology adopted to revenues or expenditures, since we collect the latter only for the 12 month period preceding the survey. Similar constraints apply to examining the proportion of establishment employment directly affected by or trained to use the new technologies, since our establishment employment data too, only coves the preceding 12 months.

Lastly, with the small sample of workers collected at each establishment, we are not able to look at within establishment worker effects directly. We can, however, compare worker outcomes between large *groups* of establishments, such as technology adopters, and non-adopters, such as we have done here. The plans for the longitudinal survey include sampling up to 25 workers from larger establishments, which may enable more “within establishment” effects of such things as technological change, to be more accurately studied.