Technological Change, the Demand for Skills, and the Adequacy of their Supply

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Il est généralement admis que la performance économique repose sur une main-d'oeuvre adéquatement formée. Les opinions divergent sur la question de savoir si le changement technologique récent a, ou non, accru l'exigence de compétences. Elles divergent aussi sur la question de savoir si l'éducation canadienne et les systèmes de formation pourvoient adéquatement ou non aux besoins en matière de compétences nécessaires. Cette étude examine ce qui ressort de ces positions divergentes, puis relève de ces discussions des implications dont fera usage la recherche académique dans les débats sur les politiques à adopter.

There is a wide consensus that economic performance rests on a suitably trained labour force. There is dispute over whether or not recent technological change has increased the demand for skills. There is also dispute over whether or not the Canadian education and training systems deliver adequate supplies of needed skills. This paper examines the evidence bearing on these competing positions, then goes on to draw some implications from the debate for the use of academic research in policy debate.

That policy-making needs to be informed by research is commonplace.[1] Policymakers are more likely to choose sensibly if they have some inkling of what they are doing. Education and training is one area in which policymakers may have considerable need of pertinent information. A frequent claim is that a well-trained and well-educated labour force is the key to competitive economic performance (Porter 1991, p. 166). It is also claimed that technological change in the last 20 or 30 years has made the need for a trained and educated labour force all the more pressing (e.g., Topel 1997). The effects of technological change on the demand for labour of varying skills, combined with the issue of whether or not the education and training systems have and can continue to deliver labour with those skills, is a matter of current policy interest.

What can policymakers learn from the existing research? Here matters get tricky. The large body of relevant research produces flatly contradictory conclusions. There are two separate questions: Has technological change significantly increased the demand for skilled labour? and, Have the education and training systems adapted to deliver the skills demanded (with reasonable lags)? In principle, either question can yield a "yes" or "no" answer. This makes possible four different pairs of answers, as summarized in Figure 1, which includes examples of those who defend each response combination. The

FIGURE 1
Technology and Skills: Theoretical Possibilities

	Supply of Skills Is Adequate	*Supply of Skills Is Not Adequate*
New technology distinctively raises skill demands	A Group of HRDC Researchers	Topel
New technology does not distinctively raise skill demands	Livingstone	Smith

fourth option — that new technology has not distinctively increased skill levels *but* that there are nonetheless in some sense meaningful skill shortages — may seem the least plausible of the scenarios. However, it is the one I defend here!

In separate sections below I examine the evidence on whether or not the spread of information technology has increased the average level of skills demanded and the issue of shortages. Since some of the evidence on skill demands is relevant to the issue of shortages the second section is shorter than the first. I draw on evidence from several economies but, particularly, from the United States. Even if Canadian policy choices are at issue, studies of the United States are useful for at least two reasons. First, the United States government and academic establishment is so huge that it generates a large proportion of high-quality research in this area. Second, since it has a much lower level of unemployment than Canada, it can provide some indication of what Canada is likely to confront as unemployment falls.

TECHNOLOGICAL CHANGE AND THE DEMAND FOR SKILLS

The innovations embodied in information technology, the argument goes, have occurred with unprecedented speed (Freeman and Soete 1994). They are also unusual in the range of areas of the economy within which they contribute to productivity improvements. They are as relevant to services as to manufacturing and resource extraction in a way that previous innovation has not been. The magnitude and speed of the changes may have put unprecedented pressures on the labour market.

Broadly speaking, two sorts of evidence are cited to suggest that new technology has increased the average skill level demanded. First, there are wages. It is often assumed that the supply of qualified employees has lagged, increasing their relative wages. This is how Berman, Bound and Griliches (1994, p. 372), for example, interpret rises in the relative wages of non-production workers. In a similar vein, some indicator of technological change (e.g., computer use) can be correlated with changes in the relative wages of skilled employees (e.g., Krueger 1993), again interpreting rises as indicating increasing demand for skilled employees and a lagging supply of them.[2] Second, there are shifts in the distribution of occupations. Berman, Bound and Griliches (1994), again for example, also present data on increases in the employment share of non-production workers. For the purposes of this paper, I am particularly interested in a version of this approach associated with a group of researchers at

Human Resources Development Canada (HRDC). In the next several sections I outline reservations with respect to the research thought to show that there is a skill-bias to recent technological change. Then I evaluate the contradictory claim that the dominant feature of the current labour market is excess skills relative to job demands. Finally, I suggest a cautious conclusion in light of the evidence reviewed.

New Technology Demands Higher Skills: Widening Earnings Inequality

Automation might increase the demand for engineers who design systems that eliminate the jobs of unskilled and semi-skilled employees. This would increase the demand for already more highly paid labour and reduce the demand for less-skilled labour.[3] Unless the education and training system adapts rather quickly this would increase earnings inequality, causing a rising earnings share for those at the top of the distribution and a falling share for those at the bottom (Johnson 1997). This sort of distributional shift occurred in the United States in the 1980s and the first half of the 1990s (Wolfson and Murphy 1998). Somewhat similar trends have been reported for other countries.[4] But there are difficulties with both the evidence of rising inequality and the new-technology interpretation of it.

Since new technology diffuses quite rapidly, the effects of it *probably* ought to show up widely across rich countries. I say *probably* because, as I note below, technology is not the only factor influencing the degree of earnings inequality. Nonetheless, the observation that earnings inequality has increased widely across countries is used as a basis for inferring an effect of technology. Thus,

> *if* technological change is an important determinant of relative demand shifts, one would expect to observe patterns in other industrialized countries similar to those in the United States. Some of the recent studies report results for a variety of old industrialized (OECD) countries that are indeed consistent with the U.S. results ... These countries vary a great deal with respect to changes in their situations with respect to trade, labor market institutions ... and unemployment. That the relative demand for skilled labor in each of them is rising rapidly is, in my view, fairly strong evidence in favor of the skill-biased technological change story (Johnson 1997, p. 49).[5]

But, while it *is* clear that earnings inequality in the United States increased in the 1980s and at least part of the 1990s, the evidence of *generality* of earnings inequality increase is less conclusive than is sometimes thought (Smith 1999). The criteria for inclusion in studies affect results. For the decades of interest here, combining men and women in a single distribution tends to reduce any increase in earnings inequality, or produce a decrease, because the earnings of women have increased relative to men, moving some of those in the lower part of the distribution toward the middle (see Wolfson and Murphy 1998). Results are also influenced by whether all employees or only full-time employees are included, and whether agricultural employees, the self-employed, or particular occupations are excluded. A case can be made that, if the purpose is to examine the effects of technology, more inclusive criteria are appropriate because within institutional limits and given the particular technology, employers will hire the combinations of labour (full-time/part-time, men/women) that maximize their profits (see Lerman 1997).[6] But most of the studies from countries other than the United States and Canada use less inclusive criteria. Moreover, the published results sometimes cover relatively short periods of time.[7]

Now, national divergencies in trends in earnings inequality can be explained by differences in either the supply of skilled labour or by wage-setting institutions (e.g., Freeman and Katz 1995). I return to the issue of supply shortly. The point I want to make here is that were rising earnings inequality general across countries, that fact would be used as evidence in support of the technology interpretation. It *is* used as evidence by Johnson.[8]

Second, it is not clear that the timing of increases in earnings inequality, where they have occurred, coincides with any identifiable acceleration in the rate of technological change. There is some evidence to the contrary. Earnings inequality rose in the United States during the 1970s and 1980s, when the standard measure of aggregate technological change, productivity growth, slowed. This slowing does not appear to have been caused by measurement problems (Sichel 1997*a*, 1997*b*). Danziger and Gottschalk (1995, p. 143) have raised the possibility that new technology has changed the demand for various types of worker without increasing productivity. But that leaves open the question: Why would employers invest in relatively costly new technology if it did not raise productivity? (Galbraith 1998, p. 29.)

Third, factors other than technology may account for changes in earnings inequality. Where earnings inequality has increased, the following other factors have been proposed as alternative explanations: trade and capital mobility (Wood 1994); increased female labour force participation (Pryor and Schaffer 1999); changes in the age structure (Macunovich 1999); and institutional changes (Fortin and Lemieux 1997). These alternative accounts have been contested with varying degrees of energy. For example, the trade account is challenged on the grounds that changes in indicators of skill levels seem not to be associated with an industry's volume of trade (Berman, Bound and Griliches 1994). But Feenstra and Hanson (1999) have argued that the standard trade figures fail to capture the effects of outsourcing which, they claim, have been important in subjecting unskilled labour in rich countries to competition from the Third World. The current state of the evidence does not allow a confident rejection of the alternative interpretations of increases in earnings inequality, where they have occurred.

For all these reasons the evidence on overall earnings inequality does not provide strong support for the claim that technological change has increased the *aggregate* demand for skilled labour.

New Technology Demands Higher Skills: Rates of Return to Skill

In most studies, skill has been operationalized as either education or experience. From the end of the 1970s the rate of return to a college education rose markedly in the United States. It also rose in many, but not all, other industrial societies for which data are available. Where it has not risen, or risen only slightly, the explanation may be increases in the supply of the college-educated workforce (Murphy, Riddell and Romer 1998). Still, there are several difficulties with the evidence on the increase in the rate of return to skill.

In the United States, an increase in the rate of return to experience is less apparent than to college education (Topel 1997, p. 58). There is evidence of no increase in the rate of return to experience in Canada (Beaudry and Green 1997). Why should one indicator be privileged over another in a test of the theory?

Second, the college/non-college differential increases if either the pay of the college-educated rises or that of those who did not attend college falls (Mishel and Teixera 1991). In the 1980s the real value of the minimum wage in the United States fell, reducing the earnings share of the lowest decile, few of whom had graduated from college.

Third, at the other end of the distribution, the rise in the rate of return to college education in the United States was produced by very large increases within a small group of occupations (physicians, dentists, and lawyers). Real earnings were static or declined within most occupations requiring a college education (Pryor and Schaffer 1999). Factors other than technology probably account for the earnings increase in those occupations, including a shift in demand toward these services produced by rising incomes and, in the case of physicians and dentists, restriction on supply.

New Technology Demands Higher Skills: New Technology Use and Pay

Other things being equal, the average pay of computer users exceeds that of other employees (e.g., Krueger 1993). But this differential appears not to originate in new, higher, and scarcer skills demanded by computer use, although that was the first interpretation of the results.[9] Panel data show that average pay does not increase in plants that adopt new technology. Nor does it increase among workers who are reassigned to using new technology. What seems to happen is that firms that adopt new technology allocate their more skilled employees to its operation. Or, firms with more highly skilled, more highly paid, workforces are more likely to adopt new technology (e.g., Doms, Dunne and Troske 1997; Chennells and Van Reenen 1997). Moreover, almost the same pay premium as is found for computer use is associated with the use of a pencil, along with having a chair and other standard office equipment (DiNardo and Pischke 1997). This also suggests that computer users are paid more because higher skilled and higher paid employees are given the equipment, rather than because the equipment requires new and higher skills.[10]

New Technology Demands Higher Skills: Changing Occupational Composition

For reasons of space I will focus on the version of this produced by a group of researchers at HRDC. They do not use indicators of shortages to support the claim that new technology requires distinctive and substantial increases in average skill levels. Indeed, their view is that there are no meaningful shortages.[11] While the literature asserting rising skill demands and a lagging supply of them focuses on earnings, the HRDC researchers' approach largely ignores them.[12] Instead, trends in skills and their sources are inferred from changes in the distribution of occupations. *Information workers* use new technology. In the first iteration of this argument these are largely found in three categories of occupations: *knowledge workers*, whose core tasks are to "produce new ideas"; *managers* whose tasks are "hardly routine, as they require judgment and some creativity for planning, directing, reading reports, and so on"; and *data workers* whose tasks "include data storage and retrieval, which are amenable to computerization given their codifiable nature" (Lavoie and Therrien 1999, p. 31).

Their evidence that technological change has increased skill demands is as follows. First, from 1971 to 1996 the annual growth of these employment categories was: knowledge workers, 4.1 percent; managers, 7.6 percent; and data workers, 2.2 percent. In contrast, service and goods workers grew by 2.6 percent and 0.6 percent respectively (Lavoie and Roy 1998, p. 23). Second, *for given levels of output*, the largest part of the growth in the employment share of knowledge workers, the emblematic information workers, is *within* industries. Lavoie and Roy interpret this to indicate technological change. Lagging productivity and growth in sales in industries with lots of knowledge workers also account for some of the growth in the knowledge-worker employment share. But their effect is smaller. Third, by industry, *computer intensity* (computer investment divided by total investment in machinery and equipment) predicts growth in the share of knowledge and management workers (Lavoie and Therrien 1999). Fourth, all three categories of information workers (knowledge workers, managers, and data workers) have higher average education and literacy levels than do either goods or service workers (Massé, Roy and Gingras 1998).

This, then, is an argument in terms of changes in the composition of the occupational structure. It attempts to demonstrate that the demand for skill has been rising because employment in occupations made up of information workers has been growing faster than employment in other occupations. How persuasive is the evidence presented in support of it? There are several difficulties. Table 1 puts the growth in the knowledge-worker category into perspective. The first column of data shows aggregate growth. This is the growth upon which the HRDC researchers' analysis focuses (but presents as annual averages). It shows that knowledge employment grew more than services, goods, or total employment. Within the broader knowledge category, computer employment — the occupational category most clearly related to the computer revolution — grew even faster. That column tends to support their interpretation.

TABLE 1
Aggregate Growth and Shares in Growth, 1971-1996

	Aggregate Percent Growth	*Percent Share in Growth*
Knowledge Employment	173.83	
Computer	637.50	20.56
Social Sciences and Humanities	180.53	54.84
Computer-Affected Employment	112.98	
Knowledge	173.83	18.38
Managers	531.05	28.74
Data	72.91	52.88
Total Employment	69.90	
Knowledge	173.83	13.13
Services	88.34	18.32
Services+Goods	35.81	28.58

Source: Lavoie and Roy (1998, p. 23).

The second column of data presents the contribution of occupational categories to the overall growth of larger categories. It shows that social sciences and humanities occupations contributed almost three times as much as the computer category to the growth of knowledge employment; among the *information employment* categories managers account for much more of the growth than knowledge workers, and data workers very much more; services contributed more to growth in total employment than knowledge employment; and services and goods production combined contributed more than twice as much as knowledge employment. The reason for this is that while services and goods production grew at a slower rate than knowledge workers, they each account for a much larger percentage of the total labour force.[13] Knowledge employment, it is true, has grown at a higher rate than most other occupational categories. Still, the magnitude of the increase tends to be overstated if attention is confined to average annual rates of growth rather than relative contributions to total growth, or employment shares.

Were technological change the master force at work here, the findings above raise two questions. Would one expect the bulk of its effect to be on employment in social sciences and humanities? And why did its effect show up in more growth of management than of knowledge occupations, and still larger growth of the more codifiable data employment? These are questions about the skill levels of the occupations that are assigned to the information-worker category.

Tables 2 and 3 address this latter, general, issue. Table 2 lists the ten occupations within each of the HRDC researchers' computer-affected categories that contributed the most to the growth of the aggregate category, ranked in terms of the size of their effect. The percentage column gives the magnitude of their contribution. In addition, since the standard assumption in most treatments is that pay is directly associated with skill, Table 2 also presents the average (full-time, full-year) 1990 earnings for the occupations listed and Table 3 presents average

TABLE 2
Share in Growth of Each HRDC Computer-Related Occupational Category, 1986-1991

Knowledge Workers			*Managers*			*Data Workers*		
SOC/Occupation	*Earnings*	*%*	*SOC/Occupation*	*Earnings*	*%*	*SOC/Occupation*	*Earnings*	*%*
2183 Systems analysts, computer programmers, and related occupations	40,981	22.7	1149 Other managers and administrators, n.e.c.	43,530	34.4	5135 Sales clerks and salespersons, commodities, n.e.c.	27,069	15.9
1171 Accountants, auditors and other financial officers	42,307	18.8	1137 Sales and advertising management occupations	39,617	12.4	4197 General office clerks	25,512	11.6
2343 Lawyers and notaries	76,966	5.4	1146 Farm management occupations	45,325	10.7	4133 Cashiers and tellers	17,766	10.2
2143 Civil engineers	49,607	4.8	1142 Services management occupations	28,752	8.6	4171 Receptionists and information clerks	21,350	5.7
2711 University teachers	62,064	3.8	1135 Financial management occupations	50,142	7.8	5130 Supervisors, sales occupations, commodities	30,774	5.4
3111 Physicians and surgeons	102,370	3.6	1143 Production management occupations	48,324	5.5	2739 Elementary and secondary school teaching and related occupations	31,910	5.4
3351 Writers and editors	37,918	3.4	1136 Personnel and industrial relations	46,796	4.4	4143 Electronic data processing equipment operators	25,874	5.3
2144 Electrical engineers	49,429	3.1	1145 Management occupations, construction operations	58,059	3.3	4111 Secretaries and stenographers	24,016	5.3
3313 Product and interior designers	29,037	2.7	1113 Government administrators	49,331	3.0	1179 Occupations related to management and administration	40,938	4.8
2157 Community planners	49,509	2.6	1116 Inspectors and regulatory officers, government	41,151	2.3	5172 Real estate sales occupations	40,310	3.5

Note: Earnings are for full-time, full-year employees.
Sources: Statistics Canada (1991, 1993, Cat. Nos. 93-327-XPB, 93-332-XPB).

TABLE 3
Mean Annual Earnings: Occupational Groups, 1990

	Earnings *$*
Occupations in natural sciences, engineering and mathematics	43,210
Occupations in social sciences and related fields	44,958
Managerial, administrative and related occupations	44,879
Teaching and related occupations	42,361
Occupations in medicine and health	39,544
Clerical and related occupations	25,087
Sales occupations	31,822
Service occupations	24,462
Processing occupations	31,360
Machining and related occupations	32,826
Product fabricating, assembling and repairing occupations	29,987
Construction trades and occupations	35,101
Transport equipment operating occupations	33,084
Material handling and related occupations, n.e.c.	28,655
Other crafts and equipment-operating occupations	35,237

Source: Statistics Canada (1991, 1993, Cat. No. 93-332-XPB).

earnings for a set of broad occupational categories. This information on earnings gives us some indication of the extent to which the occupations that account for growth *within* the HRDC researchers' computer-affected categories can reasonably be regarded as highly skilled.[14]

These tables show the following, (i) at first sight consistent with the HRDC researchers' interpretation, the largest contributor to knowledge-worker growth was Systems analysts. Less consistent is that in 1990 only two other groups of knowledge workers listed in the table had earnings lower than Systems analysts. Surely, a highly skilled occupation, in high demand, should be paid more? That Systems analysts earned less than the average for either the Natural sciences and engineering or Social sciences and related fields raises similar concerns. (ii) Growth in the employment of Lawyers and notaries, Civil engineers, University teachers, Physicians and surgeons, Writers and editors, Product and interior designers, and Community planners *might* have something to do with new technology. But it is as likely that it has much to do with income-induced increases in demand for the services they provide. (iii) More than a third of growth in management came from the grossly heterogeneous Other managers and administrators, n.e.c. All but three of the top ten management occupations had higher average earnings than that category. (iv) Two of the three data occupations contributing the most to growth in the category involve sales. But it is not clear that the computerization of sales transactions has led to an increase in the skill of sales personnel. Moreover, Cashiers and tellers had the lowest earnings of any data occupation, lower than any of the averages for the broad occupational groups described in Table 3.[15] (v) Most of those in the data categories earned, on average, less than the goods workers who, in the HRDC researchers' view, embody the lower skilled work, the declining share in employment of which is an indicator of the emergence of the knowledge society. Overall, I would argue that the concentration of areas of growth *within* so-called knowledge occupations, indicated in Tables 2 and 3, is not very consistent with the rising skill levels interpretation.

It is possible that the results I have presented above may be explained away. Some of the data occupations contributing the most to growth in the category have many women in them. So the differential may reflect institutional limits on female pay. Or, youth may be overrepresented in growing occupations. Or, mean earnings in the goods-producing occupations may be artificially raised by unions. Still, before drawing a confident conclusion about the effects of technology on the demand for skill it would be appropriate to address these earnings anomalies.

The questionable character of some of the HRDC group's classification decisions is confirmed in a paper by Boothby (1999). The results of a discriminant analysis to check the validity of the previous classification led him to the following, substantial modifications: (i) the separation of data workers into two parts, one involving, for example, technicians; the other, which he calls "data manipulation" involving secretarial and clerical employment; (ii) the reallocation of the apparently quintessentially (but not well-paid) knowledge category, systems analysts, to the data category, along with product and interior designers, thereby reassigning the sources of more than 25 percent of the growth of employment in knowledge occupations from 1986 to 1991; (iii) the reassignment of six of the ten data worker categories in Table 2 to the less-skilled data manipulation category, including the four that had the largest effect on growth in the category.[16] There are good reasons to be fairly sceptical about the HRDC researchers' initial conclusions.

What about the educational levels of the information workers? Knowledge workers, managers, and data workers (in this case, in the initial aggregated category) are more likely to have completed university than other employees (Lavoie and Roy 1998, p. 21). Cross-sectional data on cognitive capacities show that knowledge workers, managers, and data workers on average score higher on cognitive tests than do data manipulation, services, and goods workers (Boothby 1999; cited by Massé, Roy and Gingras 1998, pp. 16-20). Employment in occupations with higher average cognitive scores has grown more rapidly than other occupations.

Does this indicate rising average skill levels? It may do. Yet Boothby's (1999) data show that, of the managers who are, according to the HRDC researchers' approach, engaged in conceptual work, around 30 percent have very low scores on the cognitive tests.[17] This implies that a lot of managers are doing undemanding work (unless they are doing demanding work very badly). About 75 percent of them did not complete university. Among data-manipulation workers, most classified in the broader data category in Lavoie and Roy's (1998) paper, the incidence of very low scores is quite high — about 40 percent (Boothby 1999, pp. 17-18). Even the refined data category, with sales and clerical personnel excluded, contains between 10 and 20 percent with very low scores.

The real issue is: Is the growth in jobs in the occupations defined by the HRDC group as information work concentrated in the more cognitively demanding part of the distribution? There is, apparently, no longitudinal data available that would allow us to determine this. We do know that, while a minority, the proportion of university graduates in jobs requiring lower General Education Development (GED) scores (11 or less years of schooling) has gone from about 15 percent in 1981 to almost 20 percent in 1991. Graduates in those jobs tend to have poorer cognitive skills (Boothby 1999, pp. 37-40). Now, the assumption behind the knowledge economy interpretation must be that graduates with low cognitive skills are confined to jobs outside the information sector, but that information-sector jobs require a university education. In fact, this is implicit in Boothby (1999, p. 39), where it is assumed that all university graduates employed in the information sector are appropriately matched to jobs that require their education. But quite significant proportions of graduates (25-45 percent, depending on the measure) in the information sector have indifferent to poor cognitive skills (Boothby 1999, p. 40). The data so far available do not allow us to rule out the possibility that some of the growth in employment in the HRDC researchers' "information occupations" has been composed of individuals with cognitive abilities that are unlikely to allow them to perform high-skilled tasks. The general point is that most occupational categories are made up of a wide enough range of detailed jobs to allow an equally wide range of skills to be associated with their performance.

The HRDC researchers' case to the effect that new technology has distinctively increased the average levels of skills demanded is not an overwhelming one.

New Technology Does Not Demand Higher Average Skill Levels

Livingstone (1999) has argued that the most salient feature of the Canadian labour market is *overqualification*.[18] Three sets of data are key in his analysis.

First, based on the *Dictionary of Occupational Titles* in the United States and the *Canadian Classification and Dictionary of Occupations*, there is a series of studies of changes in average skills in detailed occupations (e.g., Myles 1988; Myles and Fawcett 1990). These tend to suggest some skill upgrading though, Livingstone (1999, p. 141) argues, disproportionately concentrated between 1940 and 1960, when many low-skilled jobs were eliminated. But, he notes, there are many methodological problems with these studies.[19] Taking them into account, he concludes:

> Overall, the weight of available empirical evidence suggests that there has indeed been a net upgrading of the technical skill requirements of the North American job structure since the 1940s. But the most substantial gains occurred prior to 1960 and the slight upgrading that is discernable since then reveals the related upgrading claims of most post-industrial/knowledge economy theorists to be quite exaggerated (Livingstone 1999, pp. 147-48).

The second kind of evidence uses estimates of the GED level required for jobs. These are compared with the achieved level of education of job-holders (mapping GEDs against years of schooling). There are, again, a number of methodological difficulties.[20] But most studies find that more employees are overqualified than underqualified for their jobs. Moreover, in North America the excess of the overqualified increased from the beginning of the 1970s to the middle of the 1990s. The third kind of evidence is subjective. When asked whether they are over- or underqualified for their jobs more respondents give answers suggesting that they are overqualified.

For Livingstone, these data show that increasing educational levels embody credential inflation rather than rising skill demands. Employers raise educational requirements because there is a larger body of certified candidates available; and labour market entrants (or re-entrants) accumulate more certification because that is what employers require. There is a spiral in which certification is increasingly detached from job demands (see Collins 1979). Consequently, the rising educational levels that are at the core of the HRDC researchers' view are not an indicator of the effect of technological change on the demand for skill, except to a marginal degree.

How is this divergence possible? The answer rests in different interpretations of educational qualifications. With the exception of the paper by Boothby, the HRDC group's work assumes that university degrees certify advanced competencies and that if those holding them are absorbed into the labour market at salaries that preserve the existing pay differential with respect to those who did not go to university that must indicate that there is a demand for those advanced competencies. For Livingstone, in contrast, whatever competencies go with them, rising educational qualifications are a screening device, and individuals try to better position themselves with respect to the screening process by acquiring more of them.[21]

Which interpretation of educational qualifications is correct? For the HRDC group the critical datum is the relation between the trend in the college/non-college pay differential and the supply of university-trained labour. In Canada there has been a small decline in the college/non-college pay differential since the early 1970s (Bar-Or *et al*. 1995; Murphy, Riddell and Romer 1998, p. 284; Gingras and Roy 1998, p. 19). But the size of the increase in the supply of university graduates exceeds the decline in the differential. *A fortiori*, the differential rose in the United States. Therefore, the reasoning goes, the demand for more skilled, that is, university trained, employees must have increased. This is, at first sight, a powerful argument that Livingstone, as far as I can see, has not addressed. But it is not quite as conclusive as it might seem.

First, there is quite a lot of evidence that, in the labour market, differentials do not immediately change in response to shifts in demand and supply. Custom slows those changes. Phelps Brown's (1977, pp. 86-89) analysis of the white-collar/blue-collar differential suggests considerable lags, certainly involving decades. In Canada, for example, in contrast to the United States, the relative pay of teachers tended to hold up quite well through periods of considerable oversupply in most fields (Economic Council of Canada 1992, pp. 72-73). This outcome, I assume, rests on a number of institutions, including the relative effectiveness of trade unions. I would have thought it difficult to explain in terms of an effect of technological change. Moreover, since quite a lot of university graduates have been employed by government, and are unionized, similar processes may well have protected their relative pay level.[22]

Second, even if we dismiss long adjustment lags, as Pryor and Schaffer show, *average* differentials can be grossly misleading. In the United States, very large increases at the top of the earnings distribution, probably associated with demand increases and supply restrictions have concealed earnings stagnation or decline across a range of occupations within which university graduates are typically found.

Third, there is research from within the HRDC group on the employment experience of recent graduates who had graduated from two to five years prior to their interview (Lavoie and Finnie 1997). It suggests the following: (i) across the period 1982 to 1990, about a quarter of holders of bachelor's degrees reported that they did not use the skills they had acquired within their program of study; (ii) holders of degrees in pure and applied science were more likely than the graduate average to report that their skills were not used; (iii) many more graduates reported that they were overqualified for their jobs than that they were underqualified, especially at the master's level, where more than half reported that they were overqualified.

Once again, these data can hardly be seen as definitive. Still, they do on balance tend to reinforce a view that is sceptical with respect to the claim that technology has been increasing the demand for skilled labour, where skilled labour is operationalized as holding a university degree.

Have the Demand Effects of Technological Change Increased Average Skill Levels?

The most prudent conclusion is that the recent technological change has not distinctively increased the average level of skills demanded. But what does *distinctive* mean? The HRDC group's view is that growing employment in information occupations reflects the effect of the computer revolution. Now, in the past, *most* of these occupations were labelled professional, managerial, and clerical. They have been growing more rapidly than others throughout the postwar period (e.g., Delehanty 1968; Employment and Immigration Canada 1981, p. 24).

Can this steady shift from manual to white-collar work be attributed to computer technology and be construed to indicate rising average skill levels? The correct answers are, I think, *no* and *probably not*. The shift to white-collar work cannot be attributed to the computer revolution because it antedates it. And to conclude that the shift to white-collar work indicates rising skill would probably be to confuse literacy with high-level skills.

Consider this latter point in more detail. The proportion of jobs for which literacy is a requirement or an asset has increased (Form 1987). Literacy is an identifiable skill. But it does not exhaust the range of work-related competencies that might involve a substantial amount of learning. It may or may not take longer to learn to read and write than to become a farrier, a blacksmith, or a competent farmer. But, in practice, those occupations demand real skills that could not be acquired in short periods of time. This point was made, famously (but with some exaggeration) by Braverman (1974). That there was ultimately an excess supply of people with those skills is not in itself a gauge of their *level*. It is to some degree a gauge of shifting demand. When railroads and the internal combustion engine replaced horses the demand for farriers fell. But that need not imply that their skill level was or is lower than mechanics, for example.[23]

This is not simply an eccentric example from economic history. We know that the balance of supply and demand shifts between occupations that require equal skill levels. In Canada, electrical engineers have been in short supply for some time; civil engineers have probably been in surplus.[24] The rise in demand for electrical engineers originates in the computer revolution. The relative decline in demand for civil engineers originates in several things, including delays in infrastructure investments. The point is that, to the extent that a scarcity of electrical engineers has replaced a scarcity of similarly skilled civil engineers (during earlier aggressive road construction phases), its existence implies no increase in skills demanded.

Nor does this only apply to high-level skills like engineering. HRDC's administrative forerunners have periodically identified trades as occupations for which supply is inadequate. Do electricians (plumbers, millwrights, tool and die makers) have less skills than many of those in so-called information occupations? That they may not is particularly likely in the quantitatively more important managerial and data occupations where, in any case, many employees have quite low literacy levels. But, even in one of the knowledge occupations, do librarians, archivists, and conservators have more skill than an electrician? The answer is not self-evident.

So, I would argue, quite apart from the fact that rising demands for literacy do not seem to coincide with any identifiable sequence of technological innovation, literacy is simply one skill among many. It may not be legitimate to infer a demand for increased skill from the fact that more jobs need it. It is just as plausible, I think, to argue that it embodies a shift in the *basis* for skills.

Is There a Skill Shortage?

Of the United States, Topel has claimed: "There is no evidence yet that the growth in the supply of skilled workers has kept pace with rising demand" (1997, p. 71). This necessarily follows from the use of pay premiums and inequalities as evidence of increasing skill levels. How good is the evidence indicating that there is a shortage of skilled labour there?

As we saw above, the pay premiums to new-technology users probably reflect the transfer of more highly paid skilled employees to different or modified tasks. *Part* of the increase in earnings inequality is caused by a fall in pay at the bottom of the distribution. However, Pryor and Schaffer's analysis (1999, p. 154) suggests that there is a handful of occupations involving university training that accounts for the growth in relative pay at the top of the earnings distribution. They have been in short supply.

Gingras and Roy present a different picture for Canada. Using different reasoning, so does Livingstone. For Gingras and Roy (1998) the critical evidence is the following: compared to other countries, Canada has a high proportion of the relevant cohorts receiving tertiary education; the supply of university-educated labour has grown faster than the supply of jobs requiring a university training; and there is no evidence of a rising wage premium to extra education.

The evidence from the United States, then, suggests localized shortages (doctors, lawyers, pharmacists), and the evidence on Canada presented by the HRDC group suggests no shortages at all. I am persuaded that there is no *general* scarcity of university-educated labour in Canada. But let me now suggest a different way of approaching the issue. Consider the following studies.

Whittaker (1990, pp. 132-33) compared work organization in a set of machine tool-using plants in Japan and Britain. The British employees had lower levels of schooling than their Japanese counterparts and more difficulty switching to the operation of numerically controlled machine tools. A fundamental problem was their incapacity to read and use equipment manuals. Training was consequently more difficult, more expensive, and less successful.

Prais (e.g., 1995) compared training and productivity in Britain with a number of other countries using matched samples of employers. The comparison with Germany generated the following conclusions. First, the British education system performed about as well as the German in producing high scorers on various cognitive tests. It did much worse in the intermediate to low ranges of the distribution. In Britain the average scores of those in the lower part of the distribution were markedly lower than they were in Germany. Second, German employers could push responsibilities lower in the organizational hierarchy than their British counterparts. German machinists were more likely to work directly from technical sketches (ibid., p. 69), German hotel clerks could be assigned some accounting tasks (ibid., p. 60), and so on. Average German productivity levels were much higher.

Mason and Finegold (1997) compared plants in the United States and several European countries. In general, US plants were more productive than their European counterparts, despite the fact that most of their employees were less well-trained. In part, their higher productivity level originated in economies of scale, linked to the size of the US market. In addition, US management had come to terms with the skill mix of its employees by relying on simplified work operations and the active involvement on the shop floor of graduate engineers who implemented changes, provided support to relatively unskilled operators, and trouble-shot as necessary. This example shows that there are alternative routes to efficient operation. In part, however, the US route depended on very large production runs. And an implication of Mason and Finegold's analysis is that, given the available skill mix, US employers had no choice in the matter.

As part of a broader examination of the US education system, Murnane and Levy (1996) conducted case studies of the recruitment of candidates for jobs in two automobile plants. The condition for hiring into the plants was a high school diploma. There was a very large number of applicants and the employers invested heavily in selection, involving consecutive waves of cognitive and other testing. They were testing for, among other things, ninth grade cognitive skills. One might think that almost all high school graduates would meet the ninth grade standard of performance. But in 1992 almost half of 17-year-olds in the United States failed to meet that standard (1996, pp. 34-35).[25]

These studies suggest that the abilities of those graduating from secondary schools and technical colleges, who still make up the bulk of the labour force, *matter* to productivity and that there appears to be systematic variation between countries in this respect. The more able of these graduates feed into what Mason and Finegold call "intermediate" skills, that is, skills not normally associated with university training.[26] Some forecasts suggest that the bulk of employment growth over the next decade or so will involve intermediate skills (Gallagher and Sweet 1997, p. 187). The corollary is that focusing on years of education, or the percentage of university graduates, as indicators of national employment-related cognitive skills, can be misleading.

Here I want to identify two forms of possible intermediate skill shortages. First, there is the question of the broad cognitive capacities of the occupations that I identify as locations of intermediate skills. Second, there are specific technical skills associated with manual trades.

Table 4 bears on the question of cognitive skills. It is drawn from the *International Adult Literacy Survey* (OECD and Statistics Canada 1995). The data were collected in 1994 and involved tests of cognitive capacities in reading, the interpretation of figures and tables, and quantitative skills. In this table I associate technicians, clerical employees, and craft employees with intermediate skills. Technicians and craft employees will normally have some certified training. Clerical employees will need to be reasonably literate. Technicians and clerks would fall within the HRDC researchers' information occupations. Craft employees would not.

The first three data columns present proportions in each occupational category using selected skills.[27] The proportions are averages of between two and four skill components.[28] The table shows, for example, that the average proportion of Canadian technicians who reported using each of several reading skills was 53.8 percent, compared to 77.5 percent among Swedish technicians. Canada's ranks are in parentheses next to its percentages. A lower average percentage using a skill gives a lower rank (where 1 indicates the best performance and 7 the worst). In general, the table shows that Canadian employers tend to demand less. The mean rank for Canada is approximately 5.8.

The last three columns of data present proportions in the designated occupations with low scores on the three cognitive tests.[29] In this section of the table a higher percentage indicates poorer performance. Thus, 30.7 percent of Canada's technicians achieved low scores as compared to 19.8 percent of Swedish technicians. Again, Canada's rank is indicated. Canada does better in these scores, though not spectacularly so. Its average rank is 4, in the lower half of the list of seven.

It is likely that Canada's performance is poorer than these figures suggest. The unemployed have lower cognitive skills than do the employed (OECD and Statistics Canada 1995, p. 59). Lower unemployment, therefore, draws those with lower cognitive capacities into employment, and some of those with lower cognitive skills who are already employed are likely to move up into higher occupational categories. At the time of the survey, Canada had a higher rate of unemployment than any other country included in the survey.[30] In fact, using the small sample of seven political units included in Table 4 as cases, there is a negative correlation between each occupation's percentage with low scores on each test and the rate of unemployment. Countries with higher rates of unemployment tend to have lower percentages with low scores. If the Canadian score is adjusted to take into account the effect of unemployment, its proportion of low scorers rises by between 2 and 22 percentage points, depending on the particular occupation and skill involved.[31]

Table 4 suggests that Canadian employers expect less of their employees in intermediate occupations and that they have reason to do so.[32] This result is consistent with studies of the cognitive performance of Canadian school children at various ages as compared to those of other countries. Canadian averages have been located at the middle or bottom of the distribution, and relative performance in science and mathematics falls with age (Economic Council 1992, pp. 45-55).

In the context of the studies reviewed above suggesting that cognitive skills are important to better

TABLE 4
Intermediate Occupations: Skills Used and Mastered

	Percent Using			Percent Scoring Two or Less		
	Reading	*Writing*	*Numeracy*	*Prose*	*Document*	*Math*
	%	%	%	%	%	%
Technicians						
Canada	(7) 53.8	(7) 36.9	(7) 35.4	(5) 30.7	(1) 15.6	(5) 21.6
Germany	74.4	65.3	39.3	26.8	16.3	17.1
Netherlands	62.5	45.3	45.6	22.3	17.7	20.3
Sweden	77.5	53.6	44.1	19.8	17.6	18.5
Switzerland (French)	61.8	47.8	44.6	37.9	37.3	22.4
Switzerland (German)	68.9	65.3	47.2	33.4	26.8	23.1
United States	67.4	54.2	47.8	18.7	21.2	13.1
Clerks						
Canada	(7) 50.0	(6) 43.6	(1) 46.1	(3) 33.8	(3) 35.0	(6) 39.5
Germany	70.7	62.7	40.7	48.6	36.5	31.3
Netherlands	55.3	36.4	42.4	30.2	25.3	31.2
Sweden	74.6	49.8	38.6	21.9	18.0	18.6
Switzerland (French)	57.5	51.0	32.5	42.6	37.5	28.3
Switzerland (German)	64.1	54.9	29.3	44.3	39.1	34.9
United States	59.9	55.8	43.4	37.1	45.1	42.3
Crafts						
Canada	(7) 38.0	(6) 31.3	(4) 53.3	(3) 52.8	(4) 55.2	(6) 56.7
Germany	59.7	40.8	39.5	50.0	39.7	27.0
Netherlands	37.8	26.7	51.3	55.0	45.3	42.0
Sweden	54.6	42.5	54.8	36.4	25.7	25.9
Switzerland (French)	54.9	42.0	53.3	60.9	50.6	40.6
Switzerland (German)	54.9	42.7	52.2	71.3	58.8	48.0
United States	47.4	42.9	62.3	67.4	67.5	60.2

Note: Canada's rank in parentheses — rank of 7 indicates worst performance.
Source: OECD and Statistics Canada, selected tables.

performance in intermediate occupations and to overall productivity, this comparative data raise the possibility that there is a *shortage* of such skills.

A second possible form of intermediate skill shortages is in the trades — electricians, millwrights, tool and die makers, and so on. There is some evidence of a chronic shortage of these in Canada. There were complaints by employers at the turn of the century (Lépine 1987, p. 42). Concerns have been expressed recurrently in the postwar period (Canada. Department of Labour 1957, pp. 13-23; Canada. Employment and Immigration Canada 1981, pp. 161-64; Economic Council of Canada 1982, pp. 39-41). There has been some evidence of excess vacancies in some trades even when unemployment was rising (e.g., Meltz 1982, p. 20). There is also evidence that employers have had to adjust to accommodate to shortages of trade skills, including settling for employees with marginal skills (ibid., p. 32; Lépine 1987).

The point is that, if an historical pattern of relative scarcity is established, employers will have had to organize production to adjust for that (as in the US firms studied by Mason and Finegold).[33] But that does not mean that they would not be better off if they had been able to organize production on the assumption of a more reliable supply of the relevant skills. The evidence that this is the case is quite strong for the United States. There is less such evidence for Canada. But that may be because there has been less relevant research conducted in Canada. The similar historical dependence on immigrants to fill trade jobs in both countries combined with the evidence of major problems in the operations of apprenticeship programs in Canada (e.g., Sharpe 1999, pp. 18-23) increases the likelihood of a similar outcome.[34]

In any case, it is on the basis of poorer cognitive scores among those in occupations requiring intermediate skills and intermittent supply problems for some of them — particularly those requiring apprenticeships — that I assign Canada to its particular cell in Figure 1.

Conclusion

An abundance of literature urges the centrality of education and training in economic performance. Consequently, the performance of the education and training system should be at the heart of government policy preoccupations. We can all agree that policymakers can only profit from knowledge generated by careful academic research. But, it turns out, the accumulated research on two connected aspects of education and training — technological change and the demand for skills and the capacity of the training system to meet those demands — offers flatly contradictory interpretations of what is going on. This pattern of contradictory interpretations is probably present in many or most policy areas. This is a bit worrying. If it is generally the case it says nothing very positive about the capacity of the social sciences to produce reliable knowledge for purposes of policy formulation. Moreover, it implies that policymakers often can find research somewhere that will support their interpretations. The producers of alternative interpretations often ignore each other, remaining content to work within an intellectual environment defined by the like-minded. Livingstone, for example, seems to have largely ignored the research on earnings that has been interpreted as indicating that technology increases skill demands.[35] In particular, he ignores the failure to fall of the earnings premium to higher education, despite marked increases in supply. The HRDC researchers seem unaware of Livingstone's work, or the research on which it is based.

In the particular substantive case here, technology and skills, the sensible starting point is a confession of uncertainty. The quality of data and interpretation will not warrant a confident conclusion. Nonetheless, I think that the most plausible interpretation suggests, first, that the information technology revolution has not led to a distinctive increase in skills demanded but that, second, the evidence warrants a less sanguine evaluation of the performance of Canada's education and training system than is found among the HRDC studies.

With respect to technology and the demand for skills I note, first, that the standard sets of evidence on earnings cited in support of the "skill-bias" interpretation — widening earnings inequality, rates of return to education and experience, and correlations between pay and technology use — are, in fact, equivocal. Second, the view that changes in occupational composition provide evidence for this interpretation rests on a set of problematic associations between particular kinds of occupation and higher skill levels. Moreover, the proponents of the skill-bias view ignore evidence, particularly associated with Livingstone, that suggests fairly widespread overqualification rather than underqualification. Because of the weakness of the evidence in support of the skill-bias interpretation I argue that the most plausible conclusion is that recent technological change has not distinctively raised average skill levels though, like past technological change, it has shifted skills around, as new occupations are created and old ones (draughting?) are destroyed.

The premise behind the HRDC studies is that the Canadian educational system does well in adapting to the changes in the demand for skills implied by new technology. The main evidence of this adaptability is increases in the numbers of university graduates. But this evidence is unsatisfactory. It says nothing about the coincidence of the skills of the graduates and what employers demand.[36] It also rather quickly glances over the high incidence (about 14 percent) of surprisingly low literacy skills among graduates. It is an account that is also largely indifferent to the skills of the bulk of the labour force, who do not graduate from either university or other postsecondary institutions. Evidence from other countries suggests quite strongly that the literacy of those with what I have called "intermediate skills" matters. Further evidence suggests that Canada does less well in this respect than many of its commercial rivals.

My argument is that there may be a shortage in the sense that an improvement in the cognitive abilities of those in, and available for, intermediate skill positions would probably expand employers' options with respect to work organization, and improve work performance and productivity growth. The particular definition of shortage used here would probably be described as normative by Roy, Henson and Lavoie (1996, p. 17), in the sense that I am contrasting *what is* with what *should* be (emphasis in the original), or, at least, what *might* be. The main reference point for what might be is the performance of other countries.[37] For purposes of policy, this would seem to represent a reasonable definition of shortage.

Notes

[1]This is the rationale for the federal government's recent *Policy Research Initiative*.

[2]The studies cited here are aggregate. There are also micro studies. For example, in Canada, Baldwin and collaborators (e.g., Baldwin, Gray and Johnson 1997) use a variety of indicators designed to suggest that technological change increases the demand for skills including, as well as wages, data on managerial estimates of skill needs and investments in training. In interpreting the results from these studies I would emphasize that there are likely to be *transitional* expenditures and problems associated with the installation of new technology. Users of the new technology will have to be trained in its use, but that does not mean that the technology requires a higher level of skills. For example, if a secretary switches from using, say, *WordPerfect* to *Microsoft Word*, that secretary may require extra training, but it would be hard to make the case that the skill level had increased. Along similar lines, precisely because it is new, managers may have difficulties finding employees to operate it correctly. But these sorts of difficulties will tend to disappear as familiarity with the technology develops. I discuss other micro studies shortly.

[3]This is simply illustrative of the sort of mechanism through which technological change might be expected to increase earnings inequality. There may be other linking processes (e.g., Danziger and Gottschalk 1995, pp. 140-41). But, Van Reenan notes that "surprisingly few studies try to analyse the mechanisms by which technological change translates into higher demand for skills" (2000, p. 272). (I would add to this, *if* it does!)

[4]The relevant evidence is summarized in Smith (1999).

[5]The *if* is emphasized in the original.

[6]Information technology may reinforce the use of part-time and temporary labour (Osberg, Wien and Grude 1996, p. 201).

[7]Thus, the studies of the Netherlands and Sweden in Gottschalk and Joyce (1998) cover four and six years respectively.

[8]Similarly, while acknowledging supply and institutional effects, Gottschalk and Smeeding (1997, p. 653) write that "commonalities suggest that similar factors may

have affected these countries," having identified technological change as the most plausible commonality (ibid., p. 650). Berman, Bound and Machin (1998, p. 1247) also emphasize the importance of pervasiveness.

[9]Suspicion of the skill interpretation of the result was warranted from the very beginning. Krueger found, in fact, that the largest pay premium was associated with using e-mail. It is no doubt *possible* to associate this with skills required by new technology, but that takes, I think, some effort. It is surely more plausible to see this as a result of the fact that computers are given to higher paid employees.

[10]I note that, recently, Van Reenan has concluded that "considerable evidence of a positive correlation of various measures of technology with the skill structure suggests that technology is, on average, biased towards skilled labour" (2000, p. 276). Nonetheless, he acknowledges weaknesses in the relevant research: for example, the absence of direct measures of technology in much of it (ibid., p. 268), possible endogeneity bias (that is, the fact that technology is likely to be assigned to the more skilled, see ibid., p. 272); and the difficulties with establishing a common understanding of what constitutes innovation in research based on surveys (ibid., p. 270). Overall, I do not find Van Reenan's conclusion convincing. For a more detailed consideration of this evidence, see Smith (1999).

[11]See Roy, Henson and Lavoie (1996); Lavoie and Finnie (1997); Gingras and Roy (1998); Massé, Roy and Gingras (1998); Lavoie and Roy (1998); Boothby and Gingras (1998); Lavoie and Therrien (1999).

[12]Boothby (1999) does incorporate earnings in his analysis. His conclusions somewhat diverge from what seems to be the HRDC researchers' norm.

[13]Massé, Roy and Gingras (1998, p. 15) acknowledge that the overall share of knowledge occupations in total occupations "remains small." With respect to problems which I consider further on in the paper, they also acknowledge the anomalousness of the substantial share of growth of employment in the Social sciences and humanities category (ibid., p. 13), and the significant proportion of university graduates in jobs usually occupied by high school graduates (ibid., p. 30). But these anomalous results seem not to induce much doubt on their part.

[14]The discriminant analysis used by Boothby (1999) which led to the modification to the HRDC researchers' occupational schema that I discuss addresses the same issue.

[15]Category 5135 contains the sellers of cars and car parts, livestock, sewing machines, hearing aids, musical instruments, boats, drapery and upholstery, floor coverings, furniture and appliances, house trailers, books, hardware, jewelry, pets, photographic equipment, sporting goods, surgical appliances, apparel, footwear, car parts, housewares, yard goods, burial plots, and cosmetics. Few of these occupations will have been untouched by the information revolution, sales are often entered into a computer. But that need not require distinctive skills. It is difficult to see the Avon lady as the spearhead of the technological revolution.

[16]Of the remaining four, one went to management (5130, Supervisors, sales occupations, commodities), two remained data occupations (2739, Teachers; 1179, Occupations related to management and administration) and one went to a lower skilled goods production category (4143, Electronic data processing equipment operators).

[17]I define low scores as one or two on a five-point scale. Examples of level-three tasks, that those falling into this category failed to achieve, are as follows: *prose* — summarize in writing a four-line section of a manual describing how to correctly adjust a bicycle seat; *document* — determine from a bus timetable the last bus that can be taken from a designated location on a Saturday night; *quantitative* — use subtraction to calculate the percentage of men in the teaching profession in a country from a chart that gives the percentage of women.

[18]For a similar approach to skill demands in the United States see Berliner and Biddle (1995, pp. 100-01).

[19]Specifically: (i) the occupational skill scores used in these longitudinal studies are updated with a lag, sometimes a considerable one, so the reported scores may diverge from real occupational characteristics; (ii) occupational detail varies by economic sector so that the extent to which averages might be misleading varies; (iii) when scores are updated, over time comparability becomes more difficult; (iv) the validity of scores for service-sector jobs is probably lower. See Cain and Treiman (1981); Betcherman (1991, p. 96); Spenner (1979, pp. 973-74).

[20]As Livingstone acknowledges (1999, p. 80) the mapping from GED to years of schooling is both fraught with uncertainty and can substantially affect results.

[21]Livingstone seems to think that rising qualification levels coincide with rising competence. But, he argues,

the organization of work prevents employees from using those skills.

[22]For evidence suggesting that public sector employees have been somewhat better paid than their private sector counterparts, and have not done badly at preserving that differential, see Gunderson (1995). He allows that "the wage advantage may be dissipating now and in the future" (ibid., p. 129), but I think that his analysis suggests that, if that is occurring, it involves a quite protracted process.

[23]Goldin and Katz (1996, 1998) make a good case to the effect that technological change in the latter part of the nineteenth century did reduce average skill levels.

[24]*Job Futures 1996* (HRDC 1996) forecasts stable prospects for civil engineers. *Job Futures 1997-98* (HRDC 1997) forecasts an improvement to "good" prospects. Nonetheless, demands for admission to university programs suggests perceived weakness in the demand on the part of potential candidates.

[25]For evidence of particularly problematic performance caused by cognitive difficulties, see Rosenbaum and Binder (1997).

[26]For a definition of intermediate skills, see Gallagher and Sweet (1997, pp. 183-84).

[27]The study also included Poland. I have omitted it and limited the table to what I take to be comparable economies to Canada. Switzerland was divided into French- and German-language cantons.

[28]The subcategories are as follows: reading (letters, reports, manuals, diagrams, bills) writing (letters, forms, reports, estimates); numeracy (measurement, calculation). I simply averaged the percentage reporting the use of each designated skill within each of these three broader skill categories.

[29]Low scores are again defined as those below three. In the table, to save space, the quantitative test is referred to as "math."

[30]The standardized rates were as follows: Canada 10.4 percent; Germany 8.4 percent, Netherlands 7.1 percent, Sweden 9.4 percent, Switzerland 3.8 percent, United States 6.1 percent.

[31]Thus, for example, the coefficients for the equation for the craft prose score were: intercept= 80.64, slope= –3.483. Using these coefficients we can (very crudely) adjust the Canadian craft prose score to what the equation predicts, had Canada had the same rate of unemployment as the United States had at the time — a reduction of 4.3 percentage points. After this correction, the predicted proportion of craft employees with low scores would rise to about 67.8 percent (52.8+(4.3*3.48)). That is, it would rise to about the same proportion of low scorers as the US. With only seven cases few of the coefficients are significant (the craft prose score *is* significant). But the effect of unemployment on cognitive score is consistent across all occupations and measures. I think that it is reasonable to deduce a real effect.

[32]Livingstone (1999) makes a related argument: he claims that skills are underutilized because employers deliberately organize production to minimize skill demands in order to weaken their workers' bargaining power. Whether or not that is true, I tend to think that there are some problems with the education system. There is not space to properly address this issue in this paper.

[33]This interpretation would, I think, be broadly consistent with the review of research on training in the US by Lynch (1994).

[34]I cite this manuscript version of his paper with the kind permission of Andrew Sharpe.

[35]I say "largely" because Livingstone (1999, pp. 162-70) does briefly discuss trends in earnings. But the major sources claiming that technology increases the average level of skills demanded, cited at the beginning of this paper, are not discussed.

[36]For evidence of a judgement that the Ontario university system has not adjusted easily to shifts in demand, see Davenport (1996). There is no reason to think that other provinces perform any better in this respect. Note also the surprisingly large presence of private institutions in the supply of intermediate skills in British Columbia (Gallagher and Sweet 1997). I take it that this is probably an indication of perceived inadequacies in the publicly subsidized, therefore much less expensive, public system.

[37]The HRDC studies do provide some international comparisons (Gingras and Roy 1988, pp. 28-30; Massé, Gingras and Roy 1998, pp. 32-33), but all for the whole population, and most focusing on tertiary education. Nonetheless, one of their figures is very interesting for

the purposes of this paper. Massé, Gingras and Roy (1998, p. 33) show that, while Canada's mean score on one of the literacy scales ranks fourth compared to 13 countries or regions, the range of low scores is wider than most other countries. Its distribution is similar, in this respect, to that of the United Kingdom.

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