

# Some Potential Job Displacements Associated with Computer-Based Automation in Canada

THOMAS H. McCURDY

## ABSTRACT

This paper computes the range of feasible adjustment paths for the Canadian economy in response to the adoption of some computer-based-automation technologies. The paper also compares alternative scenarios which are determined by different rates of diffusion of the new technology, different degrees of dependence on foreign production of the required new equipment, and different degrees of success in export markets. The aggregative results indicate that the new job creation required to prevent technological unemployment will be relatively small. However, the disaggregative results show that the matching of (occupational) skills and (sectoral) location of the displaced workers with those required by the new technological/occupational structure will be an important issue.

## 1. Introduction

There is considerable disagreement about the employment effects of computer-based technical change. There have been many dire predictions concerning the potential net loss of jobs due to automation made possible by microelectronics. However, others argue that technological progress promotes increased productivity, real income and growth. Accordingly, if workers are displaced by machines, such technological unemployment should only be temporary since appropriately operating market mechanisms (resulting in changes in relative product and/or factor prices and in expenditure of increased incomes) would ensure that those workers are re-employed somewhere in the economy. Therefore, according to this view, the displacement of workers will be far worse if the new technology is not adopted. In an open economy, the increased competition from newly industrializing countries and from other advanced industrialized countries makes technical progress necessary in order to retain export markets and also to compete with imports. Changes in international comparative advantage and thus in the world distribution of income may be associated with the effective adoption of the new technology.

Is it possible to resolve the disagreement concerning the potential impact of technical change on employment? Without wishing to minimize the problems of adjustment (particularly for the individuals affected), earlier fears of sustained widespread technological unemployment in response to, for example, assembly line production and mainframe computers did not materialize. It is difficult to find historical examples of sustained technological unemployment. In fact it would appear that countries with a fast rate of

---

THOMAS H. McCURDY is an associate professor in the Department of Economics at Queen's University, Kingston, Ontario, Canada

Address reprint requests to Professor Thomas H. McCurdy, Department of Economics, Queen's University, Kingston, Ontario K7L 3N6, Canada

technical innovation have had low rates of unemployment rather than the other way around. Are there reasons to believe that the latest new technology (the microelectronics "revolution") has special characteristics which might make its potential (un)employment implications different from earlier technical revolutions?

It is virtually impossible to predict the aggregate and structure implications of the pervasive technological and organizational changes which are likely to result from, and accompany, microelectronic-based technical change. Nevertheless, it is possible to analyse specific aspects of the impact of this technical change. In particular, successful technical change invariably involves fewer inputs per unit output of goods and services. Many components of this new technology—such as, computer-based automation—appear to be labor saving in that the labor required per unit of output falls. This heightens fears that jobs will be lost. For example, automation is clearly a threat from the viewpoint of a bank teller whose job is being replaced by a machine and who thus must retrain for different tasks within the firm or perhaps even search for a new job in another firm or industry

However, the idea that there is a fixed number of jobs for which humans and machines compete is clearly fallacious. From the viewpoint of society as a whole, we need to recognize that new jobs are created (often indirectly) by the new technology, and that there are feedback effects of higher real incomes (the productivity dividend). That is, technical change usually improves productivity (output per person) and thus potentially improves our standard of living—either in the form of higher income or an increase in leisure in the form of shorter working hours.

Therefore, case studies of particular industries or occupations can be misleading with respect to the overall (net) effects, since job displacement is an important part of growth. Technical change and/or changing patterns of final demand will initiate structural dynamics which ultimately should lead to movement of workers from declining sectors to new opportunities in growing sectors

Nevertheless, even in the context of potential technological unemployment due to slow adjustment towards a new technological and occupational structure, there are important empirical issues. One of these issues is the potential structural unemployment which is manifested in a mismatch (for occupations (skills), sectors and even countries) of displaced positions and the vacancies created in the growing sectors. Modeling the potential sources of future occupational and sectoral shifts provides an indication of the magnitude and speed of adjustment that will be required to avoid such structural unemployment.

This paper reports results from a model which simulates some potential implications, for the Canadian economy, of the computer-based automation (CBA) technologies analysed by Leontief and Duchin [14]. CBA technologies applied to production processes (robotics, computer numerically controlled (CNC) machine tools, computer-aided design and manufacturing (CAD/CAM)) and offices (information processing equipment) are only one component of the microelectronics revolution. Therefore, this application of the model to computer-based automation has a more specific focus than an earlier application [15] and also benefits from an extensive collection of more recent Canadian data on machine tools, robots and computers. Furthermore, the CBA applications of microelectronic-based technology have more precisely quantifiable impacts on labor productivity and hence on changes in the demand for workers by industry and occupation.

Since computer-based automation reduces the demand for labor per unit of output, if output stays constant after the CBA is introduced, then workers will be displaced for some occupations and industries. However, when/if the appropriate structural adjustments

take place, those displaced workers will be re-employed and national income will increase. An increase in the rate of diffusion of the new technology will imply more initial displacement but the higher productivity gains should ultimately improve national welfare. These comparisons highlight the importance of the required structural adjustments. Our model computes the potential size of these effects at both disaggregated (by sector and occupation) and aggregated levels of detail

The results indicate that the current stages of automation should not seriously threaten the total number of jobs available. Historically, the economy has absorbed the workers who have been displaced by increased productivity and automation. The calculations of the effects of computer-based automation suggest that the magnitude of absorption or new job creation required (to prevent technological unemployment) will be relatively small when compared with that necessitated by the increased participation rates of women and the demographic bulge associated with the post-war baby boom. Nevertheless, the results also show that the impact of the new technology will be more severe for some occupations and sectors than others. Matching of skills available and those required by the new technology may not be trivial. In addition, the implications for displacement of females versus males are clearly different for office than for production applications.

## II. Summary of the Model Structure

It is difficult to predict the *net* (that is, after any structural and economic adjustments which facilitate matching of displaced workers with job vacancies brought about by the new technology) employment implications of CBA by aggregating industry studies or survey responses. Such studies<sup>1</sup> are very important as sources of information concerning the sectoral detail. Nevertheless, in order to compute the effects for structural unemployment (sectoral and occupational mismatches) and for aggregate (un)employment, it is also necessary to explicitly model: the sectoral interdependencies; the interactions between supply and demand<sup>2</sup>—such as the feedback initiated by the productivity dividend; and the potential for export-led growth by those countries which adopt a more rapid diffusion of the new technology

Earlier literature on formal modeling of the impact of microelectronics on employment has been surveyed by OECD [22]. Most of these models—notably, Bundesministerium für Wissenschaft und Forschung [1] and Whitley and Wilson [31]—are either input-output models or large scale macroeconomic models with an appended input-output structure. More recent modeling of the unemployment impact of new technology has been reported in Dungan and Younger [7], Howell [11], Leontief and Duchin [14], Office of Technology Assessment [18, 19], Roessner [25] and Rumberger and Levin [26].

Our model<sup>3</sup> integrates a 39 sector input/output structure and the national income and product accounts into a single framework. That is, an econometric model is fitted to real (1971 constant dollars) aggregate time series data to model the level of final demands, while the evolving input/output structure disaggregates those levels across detailed sectoral, occupational and commodity classifications.

Our strategy is: 1) to base the model in the actual data at a disaggregated level—

<sup>1</sup>See, for example, DeMello, McMullen and Willis [4], Globerman [10], Ontario Task Force on Employment and New Technology [21], Pilonusso [23], Policy Studies Institute [24], and Werneke [30]

<sup>2</sup>See, for example, Neary [17] and Whitley and Wilson [31]

<sup>3</sup>Additional details concerning the model structure and solution method are available from the author upon request

for example, the simulations are calibrated on an annual basis to a reference or baseline path which incorporates detailed sectoral trends for both supply and demand; (2) to compile and adapt as much information as possible at a disaggregated level concerning the labor productivity *impacts* of computer-based automation, and then utilizing this sectoral and occupational information; 3) to simulate the *net* effects of CBA when the interdependencies of the economy are explicitly modeled. In particular, we compute the range of feasible post-technical-change adjustment or transition paths for any particular scenario, and also compare the effects of alternative scenarios where the latter are identified by, for example, different rates of diffusion for the new technology.

Three solutions are computed for each year. For example, for year 1995 (or for any other year 19xx): 1995(ref) is the reference (or baseline) solution—that is, without the computer-based automation (CBA); 1995(shock) is the post-CBA solution which incorporates the effects of the CBA technical change while keeping the level (but not the structure) of final demand equal to that along the reference path; and 1995(final) is the solution in which displaced workers, computed using the 1995(shock) solution, are re-employed using the new technological/occupational structure. This final solution allows us to compute the income and associated final demands made possible by the new technology using reference solution overall employment levels.

While the model does not predict the exact level of unemployment in any given year, it does provide upper and lower bounds on the unemployment likely to arise due to computer-based automation. The latter is provided by the post-technical-change (final) solution whereas the former is approximated by the post-technical-change (shock) solution.<sup>4</sup> Which of these solutions will be closer to the actual unemployment will depend on the ability of the labor market to provide new jobs for displaced workers. If adjustments are instantaneous such that all workers displaced by the new technology are re-employed immediately according to the new technological/occupational structure, then 1995(final) will be the relevant post-technical-change solution. At the other extreme, if output remains at reference (no CBA) levels throughout the simulation, then the predicted post-technical-change solution is 1995(shock) so that very few of the displaced workers will be re-employed. Of course, additional structure on the model provided by, for example, a theory of skill acquisition, could predict a particular solution between 1995(shock) and 1995(final).

Time paths are generated for each of the above three solutions by computing those solutions year-by-year from 1982–95 using the converged values for each path in year  $t-1$  as starting values for the corresponding path in year  $t$ . The demand side evolves according to the projections of the econometric model suitably perturbed by feedback from the CBA in the case of the two post-technical-change solutions 19xx(shock) and 19xx(final). This feedback includes the income effects to factors of production from the productivity dividend,<sup>5</sup> the change in the structure of final demand, and the change in the structure and level of demand for various occupations (including employees versus

---

<sup>4</sup>Total displacement is computed using outputs from the reference solution. The difference between total employment for the pre-technical-change (reference) solution and that for the post-technical-change (shock) solution is approximately equal to total displacement since, although the level of final demand is the same for these two solutions, the change in its structure brought about by the technical change (for example, different sectoral allocations of investment and imports) will have some employment implications.

<sup>5</sup>A link between demand and supply is incorporated via an econometric estimation of the time series relationship between factor incomes (wages per employee and profits per self-employed hour) and productivity (per hour). This provides a channel through which the productivity dividend or income effect of the technological progress is transmitted to final demand.

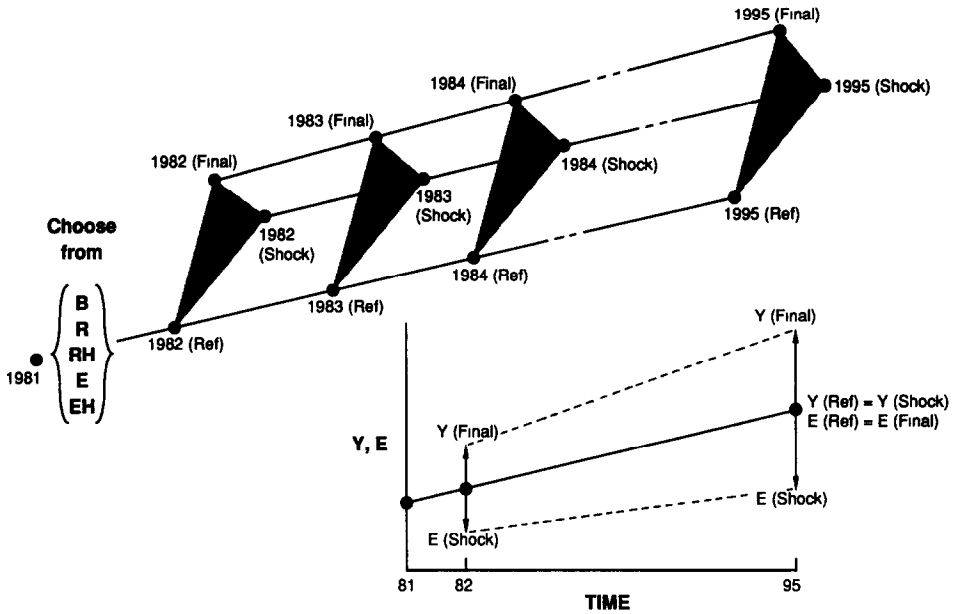


Fig.1. Calibration of post-technical-change solutions to the baseline path and comparison of the three solution paths in output and employment space.

self-employed). The supply side evolves according to the reference path chosen and the particular assumptions concerning the impact and the rate of diffusion of the new technology.

In summary, as illustrated in Figure 1, two post-technical-change paths (19xx(shock) and 19xx(final)) are computed for each scenario relative to the chosen reference or baseline path (19xx(ref)) which the alternative scenarios have in common. Solution path 19xx(final), which computes the implication of re-employing workers displaced by the CBA is very important because it incorporates the potential feedback, unlike Bundesministerium [1] and other Keynes-Leontief-type models criticized by Whitley and Wilson [31] and OECD [22]. Our two post-technical-change paths bound the range of feasible transition paths.

While it might be useful to model the *behavioral* reactions to the CBA explicitly (that is, trace a particular transition path from 19xx(shock) to 19xx(final)), this is very difficult to do empirically without additional information—for example, elasticities of demand for skills or occupations and a theory of skill acquisition. Therefore, our model does not use relative prices explicitly to predict a particular transition path.<sup>6</sup> However, all the substitution trends embodied in the annual, constant dollar, input/output use (input), output and final demand matrices at the medium (thirty-nine sector) level of aggregation are utilized. Furthermore, due to the dominant nature of the new techniques introduced by CBA, the income effects and the dynamic substitution effects (such as the changes in the structure of investment as the new technology is embodied) will be quantitatively more important than intraperiod substitutions induced by relative price changes. In other

<sup>6</sup>If detailed occupational demand elasticity estimates of the type presented in Denny and Fuss [5] for a Canadian telecommunications firm were available for all industries, the applied general equilibrium method would be a particularly attractive alternative methodology. Also, see Siedule and Leckie [28]

words, we are not distinguishing between shifts in the production function and movements along it as we track changes in the production points.<sup>7</sup> Nevertheless, the dynamic evolution of cost prices and the associated shifts in the factor price frontier could be computed as output from the model.

### III. Impact Effects of Computer-Based Automation

Considerable attention was given to matching the technical change data with the economic structure of our model. One source of widely diverging predictions for the impact of CBA on (un)employment is the failure to incorporate the fact that only a fraction of the tasks of a particular worker will be affected by the technical change and also the fact that often the impact is more similar across occupations than it is across sectors. That is, there are both important sectors (such as the electronic and the machinery and equipment producing sectors) and important occupations (such as information processing operatives, machinists, assemblers, etc.) which need to be distinguished in modeling the technical change. A further source of the divergent predictions concerning the effect of CBA is the variety of different opinions concerning the rate of diffusion.

We have addressed these issues by using shock data which incorporates: the fraction (S) of workers' hours potentially affected by computer-based automation, the labor productivity using the new technology relative to that using the old technology (P); and alternative rates of diffusion (DF) which tell the model how quickly we wish to approach the potential levels of automation in the various sectors. The post-technical-change input matrix will incorporate the fact that the same output can be produced with fewer labor inputs. Also, the inter-industry input matrix is adjusted to reflect some changes in material inputs due to the CBA technical progress

Appendices B and C in McCurdy [16] report details on sources and methods of implementation of these data which predict the impact of CBA on labor productivity and the material input requirements. This study is indebted to the Leontief and Duchin [14] study which was a major source for these data. The impact of a microprocessor-based machine doing a particular task in a particular industry should be similar in Canada and the United States. Of course, the rate of adoption of such machines and the trade implications could be very different across countries. This is one reason that we compute alternative scenarios with respect to those variables

### IV. Results

Data (sectoral/occupational employment matrices, final demand, sectoral outputs and inputs) from the post-technical-change paths—19xx(shock) and 19xx(final)—are compared to those from 19xx(ref) and decomposed according to changes originating from the supply side (productivity and input changes) versus final demand changes. A comparison of the 19xx(final) path with the 19xx(ref) path isolates the structural adjustments (occupational and sectoral) required to re-employ the workers displaced by the CBA—the latter having been computed using the difference between the 19xx(shock) and the 19xx(ref) solution paths. Displaced workers by occupation, sector and application (production and office) are reported for total displacement (both levels and percentages of base-year commercial employment) and female displacement.

---

<sup>7</sup>See de Boer and Donkers [2] for a discussion of the relationship between the input/output specification of the production technology and other specifications

**TABLE 1**  
**Employment and Displacement of Workers: Alternative Reference Paths Using Scenario 000**

Reference Path	B	R	RH	E	EH
TE	13753	12526	12846	12692	13075
CE	10246	9019	9338	9185	9568
E	9036	8058	8344	8214	8557.
SE	1216	961	994	971	1011
Cumulative Displacement (CBA)					
level	411	350	355	351	357
% of (1981) CE	5.1	4.4	4.4	4.4	4.4
% of (1995(ref))	4.0	3.9	3.8	3.8	3.7
UR(ref)	2.0	10.7	8.4	9.5	6.8
UR(shock)	4.0	12.6	10.4	11.4	8.8
UR(final)	1.6	10.5	8.2	9.3	6.6

Key B, reference path which keeps labor productivity (1/Q), interindustry inputs (A), allocation of demand across sectors (FDSTR), and average weekly working hours by industry (HW) fixed at base-year (1981) levels, R, reference path which allows Q, A, FDSTR, and HW to evolve according to their historical rates of change, RH, reference path which is the same as R except that HW is decreased by 5%—for example, from 40 hours/week to 38—that is, relative to the HW along path R, for each sector I and date t,  $HW'(I,t) = HW(I,t) \times (.95)$ , E, reference path which allows Q, A, FDSTR, and HW to evolve as in R but subtracts the impact of CBA on Q and A from the historical trends so that the reference path contains all the sources of productivity improvement except those due to CBA, EH, reference path makes the same adjustment to HW for E as in RH, TE, is total employment or CE + EH where EH is ‘hidden employment’, that is, employment not covered by commercial employment CE from the input/output-based supply side of the model, CE is further disaggregated into employees E and self-employed SE, UR(ref), is the unemployment rate for the reference (or baseline) path solution in 1995, UR(shock), is that for the solution incorporating CBA but keeping final demand at reference path levels, UR(final), is that for solution with displaced workers re-employed using the new technological/occupational structure Scenario 000 is defined in the key to table 2. Table items are in thousands of workers for the first five rows and percentages for the last five.

#### IV.1 DISPLACEMENT OF WORKERS RELATIVE TO ALTERNATIVE REFERENCE PATHS

Table 1 compares the displacement effects of CBA and the (un)employment implications of choosing alternative out-of-sample reference (or baseline) paths. With respect to choice of a reference path, one view is that the computer-based automation is revolutionary, while according to others it is evolutionary in the sense that it is a continuation of past trends of technical change. We model the former view using a reference path (R) which allows the historical trends for productivity improvement to continue out-of-sample by incorporating the extrapolated rates of change for labor productivity and the materials input structure. In that case, the post-technical-change paths (shock and final) result from superimposing the impact of CBA on the historical trends. Alternatively, the evolutionary reference path (E) subtracts the impact of CBA on labor productivity and other inputs from the historical trends (for out-of-sample simulations) so that the reference path contains all the sources of productivity improvement except those due to CBA. Then the post-technical-change paths will add the productivity improvements due to CBA such that the total effect will approximate historical trends. Both the R and the E reference paths allow the structure of final demand across commodities, and weekly working hours by sector to evolve according to historical rates of change.

Results are also reported using some other choices for the reference path. For example, one extreme version (B), which is often used in input/output based models, holds the technology, plus the structure of final demand across sectors and weekly working

hours, constant at base-year (1981) levels. In this case, CBA will be the only source of increased productivity out of sample. This is clearly unrealistic—these results emphasize the importance of incorporating the substitution and income effects for both demand and supply processes. Other choices for the reference path (RH or EH) are the same as R and E except that the sectoral average weekly working hours are decreased relative to historical trends. These reference paths allow us to evaluate the potential impact on the level of (un)employment of allowing a faster decrease in the length of the working week—a “policy” which is sometimes proposed as a solution to high rates of unemployment.

Table 1 reports that the unemployment rate (hereafter referred to as UR) for the E reference solution in 1995 is 9.5% in contrast to 10.7% for the R case. Under scenario 000 (see Section IV.2 below), the cumulative impact of CBA is to increase the UR by 1.9% to 11.4% and 12.6% for E and R respectively. However, when/if the appropriate structural adjustments take place such that the displaced workers are re-employed, the E (alternatively R) UR settles at 9.3% (alternatively 10.5%). Allowing average weekly working hours to decrease at a faster rate decreases these unemployment rates to 6.6% and 8.2% respectively.

A particular choice of reference path E will affect the *levels* of the variables—particularly the unemployment rate<sup>8</sup>—but will not substantially change the structural impact of CBA or the comparative scenario analysis for which the model was designed. Therefore, although in my opinion the reference path is the most sensible baseline for the year-by-year calibration of the model, most of the results are reported relative to the R reference path for computational reasons.

#### IV.2 ALTERNATIVE SCENARIOS

After choosing a reference path, one chooses a scenario. We have used scenario parameters (as in Bundesministerium [1] or Schmoranz [27]) in order to compute alternative scenarios for the post-technical-change solution paths 19xx(shock) and 19xx(final). The parameter DFscenario indicates the rate of diffusion of the new technology. This parameter allows us to compute the probable (DFscenario = 0) and the upper bound (DFscenario = 2) for the rate of adoption. Parameter IMscenario captures different degrees of dependence on foreign production of new CBA equipment. For example, if IMscenario equals 0, the same fraction of investment is imported as for the reference solution path 19xx(ref). On the other hand, when IMscenario equals 1 all the investment related to the new technology equipment is imported. Finally, EXscenario allows us to perturb the export path. Therefore, (DFscenario IMscenario EXscenario) equal to 000 is an example of a particular scenario choice.

Table 2 reports the implications for displacement and (un)employment of some alternative scenarios. Appendix B.2 in McCurdy [16] discusses in some detail the implications (for final demand feedback and the level of imports) of the investment requirements to embody the new CBA technology in the capital stock. Since a high proportion of machinery and equipment investment is already imported (along the reference path), importing all the new CBA equipment which is required by the rate of diffusion 0—that is, scenario 010—does not change the results a great deal relative to scenario 000. Essentially, the displacement of workers due to the application of CBA is the same but the final demand level is lower since imports are higher relative to the 000 scenario. The net effect is a 1995(final) UR which is 0.2% higher for scenario 010 relative to 000. On

<sup>8</sup>Also, the level of (un)employment predicted for 1995 is sensitive to the extrapolation of EH (the non-commercial employment) out of sample.

**TABLE 2**  
**Displacement of Workers for some Alternative Scenarios Relative to Reference Path R**

Scenario	000	010	001	200	211
CE	-3.0	-3.2	-0.7	-7.2	-5.2
E	-3.1	-3.3	-0.8	-7.4	-5.4
SE	-2.3	-2.5	0.4	-5.4	-3.0
Cumulative Displacement due to CBA level	350.0	350.0	354.0	857.0	864.0
% of (1981) CE	4.4	4.4	4.4	10.7	10.7
% of (1995(ref)) CE	3.9	3.9	3.9	9.5	9.6
UR (shock) -UR (ref)	+1.9	+1.9	+0.4	+4.6	+3.3
UR (final) -UR (ref)	-0.2	0.0	-1.7	-0.5	-1.8

Key. Scenarios are labelled by the setting of scenario parameters (DFscenario, IMscenario, EXscenario) where DFscenario indicates the rate of adoption or diffusion—0 and 2 are similar to scenarios 2 and 3 in Leontief and Duchin (1986). IMscenario indicates the fraction of CBA equipment which is imported—0 implies that the same fraction is imported as for machinery and equipment investment along the reference path, while 1 implies that all new CBA equipment is imported. EXscenario indicates the level of exports—0 and 1 imply empirically observed and a shift (increase) in the export function by 5 percent, respectively. Table items in the first three rows are percentage displacement relative to their common reference path solution, that is,  $[(1995(\text{shock})/1995(\text{ref}))-1] \times 100$ . See Table 1 for key to variable definitions.

the other hand, comparing scenario 001 with 000—that is, increasing exports by 5% for the former relative to the latter—results in a 1.5% decrease in the UR. The extra final demand due to higher exports, presumably brought about by improved competitiveness due to the adoption of CBA, almost completely offsets the displacement due to the CBA.

A much faster rate of diffusion of the known CBA technology, indicated by a DFscenario setting of 2 rather than 0,<sup>9</sup> results in more than twice the cumulative displacement (4.4% to 10.7% of the base-year commercial employment for scenario 000 versus 200). Of course, in the unlikely event that we were able to achieve such a fast rate of diffusion, we may have to import more equipment and, since we would probably be adopting CBA at a faster rate than our trading partners, we would be able to increase our exports—resulting in a scenario such as 211.

Although the cumulative displacement of workers increases as the rate of diffusion of the new technology increases, from the viewpoint of output per employed worker, a faster rate of diffusion is beneficial. Table 3 illustrates some benefits of technical progress and costs of higher imports by computing the changes in levels of income and final demand when all the structural adjustments have taken place—that is, when the displaced workers are re-employed using the new technological/occupational structure and the solution 1995(final) is attained. For example, under scenario 000 (alternatively 200), GDP is 3.8% (alternatively 9.7%) higher by 1995 than it would have been without the adoption of CBA from 1982–1995. As another example, wages per employee hour increase by 6.2% (10.1%–3.9%) when, ceteris paribus, the rate of diffusion increases from that indicated by DFscenario = 0 to that for DFscenario = 2.

#### IV.3 DISPLACEMENT BY SECTOR AND APPLICATION OF CBA

Tables 4 to 6 provide a disaggregated account of the potential impact of the CBA modeled in this paper on the number and proportion of displaced workers by sector,

<sup>9</sup>A DFscenario equal to 2 rather than 0 implies assumptions concerning the labor productivity impact of CBA analogous to the upper bound scenario in Leontief and Duchin [14]. Also, scenario 200 assumes double the number of robots in place by 1995 relative to scenario 000.

**TABLE 3**  
**Change in Aggregate Variables for some Alternative Scenarios assuming Re-employment of Displaced Workers**

Scenario	000	010	001	200	211
GDP	3 8	3 6	6 1	9 7	11 9
CONS	4 2	4 0	6 5	10 8	13 0
IVME	3 5	3 5	3 4	8 8	8 7
EX	4 0	3 8	11 4	10 1	17 7
IM	4 2	4 3	8 0	10 6	14 8
WG	3 9	3 6	7 0	10 0	12 8
WGH	3 9	3 8	5 3	10 1	11 3
PRG	5 2	5 0	8 0	13 4	16 2
PRGH	4 6	4 5	5 3	11 8	12 4

Key See Table 2 for a key to scenario definitions. GDP is gross domestic product, CONS is private sector consumption, IVME is machinery and equipment investment, EX is exports, IM is imports, WG and WGH are gross wages and same per employee hour, and PRG and PRGH are gross profits and same per self-employed hour. Table items are percentages relative to their common reference path solution for 1995, that is, [(1995 (final)/1995 (ref))-1] × 100

occupation, application (production and office) and sex. These tables are aggregated to 11 occupational groups (plus totals) with those occupations which are likely to be influenced by a particular application of CBA grouped together.<sup>10</sup>

In terms of total cumulative displacement (Table 4), it is clear that the sectors with the highest proportion (relative to 1981 employment) of jobs affected are the metal fabricating, machinery and transportation equipment industries with displacement ranging from 12.0% to 19.6%. The rubber and plastics products industries have over 10% affected, while primary metals, electrical products, furniture and fixtures, wood, miscellaneous manufacturing, and non-metallic mineral products industries, as well as services to business management, all have between 5% and 10% displacement. The disaggregation of this total displacement to application shows that most of the production displacement occurs in sectors dealing with metal fabricating, machinery, transportation equipment, construction and primary metals, while that for office applications is concentrated in wholesale and retail trade, finance, insurance and real estate, and in services to business management.

With respect to the occupational implications of production applications of CBA (Table 5), notice that negative displacement implies that the CBA creates jobs in that cell. This situation occurs for computer professionals. For some sectors, the displacement by computer-aided design (CAD) equipment (for example, draughtsmen-related jobs) offsets the job creation associated with other professionals such that there is net displacement. Also, the percentage displacement for machinists is quite high but note (from Table 8) that they constitute a very small proportion of the total employment. For scenario 000, machinists decline by 1.11% in proportional terms as compared to the pre-CBA reference path.

For occupational implications of office applications of CBA (Table 6), clerical jobs are the hardest hit—both in terms of absolute numbers and in terms of percent of 1981 employment. Finally, 34% of the cumulative displacement occurs for jobs which were

<sup>10</sup>Notice that since displaced workers are computed before final demand feedbacks occur—that is, by comparing 19xx(shock) with 19xx(ref)—only those occupations which are directly impacted by the CBA are reported for tables 4 to 6. Displaced workers by sector, occupation and application disaggregated to the 3-digit occupational classification on which our model is based (80 occupations), the mapping from 80 occupations to the occupational groups reported in this paper, and more disaggregated results on the percent of displaced jobs which were held by females in the base year are reported in McCurdy [16].

**TABLE 4**  
**Displacement by Sector and Application of CBA: Reference Path R and Scenario 000**

Sector	Production	Office	Totals	% of 1981 Commercial Employment in Sector
1 Agriculture	0 404	0 688	1 092	0 2
2 Forestry	0 753	0 240	0 993	1 6
3 Fishing, Hunting, Trapping	0 065	0 099	0 164	0 5
4 Metal Mines	1 745	0 364	2 109	3 5
5 Mineral Fuels	0 382	0 989	1 371	3 6
6 Non-Metal Mines and Quarries	0 693	0 153	0 846	4 0
7 Services incidental to Mining	0 951	0 377	1 328	3 4
8 Food and Beverage Industries	6 946	2 894	9 841	4 2
9 Tobacco Products Industries	0 195	0 093	0 288	3 3
10 Rubber and Plastics Products	5 747	1 333	7 080	11 5
11 Leather Industries	0 937	0 191	1 128	4 3
12 Textiles Industries	2 129	0 551	2 680	4 0
13 Knitting Mills	0 465	0 120	0 585	2 9
14 Clothing Industries	3 323	0 689	4 013	4 2
15 Wood Industries	7 150	0 758	7 908	7 0
16 Furniture and Fixtures	3 812	0 517	4 330	8 0
17 Paper and Allied Industries	5 700	1 304	7 004	5 4
18 Printing and Publishing	1 701	1 813	3 514	3 2
19 Primary Metal Industries	10 782	1 210	11 992	9 7
20 Metal Fabricating Industries	29 096	2 017	31 113	19 6
21 Machinery Industries	11 153	1 854	13 007	12 0
22 Transportation Equipment	22 415	2 362	24 777	13 9
23 Electrical Products	8 505	1 561	10 066	7 9
24 Non-Metallic Mineral Products	3 258	0 606	3 864	7 0
25 Petroleum and Coal Products	0 461	0 437	0 898	4 2
26 Chemical and Chemical Products	1 557	1 504	3 062	3 5
27 Miscellaneous Manufacturing	3 873	1 128	5 001	7 5
28 Construction Industry	18 309	5 370	23 679	3 4
29 Transportation and Storage	5 138	6 127	11 265	2 4
30 Communication	-1 910	5 297	3 386	1 6
31 Electrical Power, Gas, etc	2 736	1 793	4 529	4 7
32 Wholesale Trade	6 230	14 931	21 160	4 4
33 Retail Trade	13 058	40 098	53 156	3 9
34 Finance, Insurance, Real Estate	-11 189	29 134	17 945	3 2
35 Education, Health Services	-0 788	1 532	0 744	0 6
36 Amusement, Recreation Services	0 347	1 202	1 549	1 8
37 Services to Business Management	14 750	19 426	34 176	6 0
38 Accommodation, Food Services	0 135	3 932	4 067	0 8
39 Other Personal Services	12 229	2 248	14 478	5 0
Totals	193 243	156 944	50 187	4 4

Key Entries are cumulative to 1995 and are in thousands of workers A negative entry implies that jobs are created

held by females at the time of the 1981 census (our base year). Tables 5 and 6 show that this proportion is much higher for office applications of CBA than for production applications (67.1% versus 7% respectively). There are also significant differences across sectors in this regard.<sup>11</sup>

<sup>11</sup>See McCurdy [16].

**TABLE 5**  
**Displacement by Sector and Occupation for Production Applications as a Percentage of 1981**  
**Commercial Employment: Reference Path R and Scenario 000**

Sector	(NET)	Fabricators				Total
	Professionals	Processors	Machinists	Assemblers Repairers	Equipment Operatives	
1	0 1	5 8	35 4	5 8	5 8	0 1
2	3 4	7 0	46 2	7 0	7 0	1 2
3	-8 1	9 7	74 2	9 7	9 7	0 2
4	2 4	5 5	36 3	5 5	5 5	2 9
5	-7 0	9 1	67 8	9 1	9 1	1 0
6	3 2	5 8	38 0	5 8	5 8	3 3
7	5 8	6 2	39 7	6 2	6 2	2 4
8	-17 7	5 4	35 0	5 4	5 4	3 0
9	-12 1	4 1	24 8	4 1	4 1	2 2
10	-1 6	9 8	74 5	9 8	9 8	9 4
11	-19 7	4 5	26 5	4 5	4 5	3 6
12	-9 9	4 3	24 3	4 3	4 3	3 1
13	-4 8	3 0	12 1	3 0	3 0	2 3
14	-2 5	4 4	26 0	4 4	4 4	3 5
15	-5 1	5 5	36 2	5 5	5 5	6 3
16	1 7	5 5	37 0	5 5	5 5	7 0
17	-9 1	5 7	37 5	5 7	5 7	4 4
18	-3 7	4 3	26 2	4 3	4 3	1 6
19	-5 3	6 3	42 6	6 3	6 3	8 7
20	11 0	6 0	39 7	6 0	6 0	18 3
21	-13 4	5 9	39 3	5 9	5 9	10 3
22	-7 0	7 0	47 6	7 0	7 0	12 6
23	14 3	4 7	29 4	4 7	4 7	6 7
24	0 4	5 7	36 9	5 7	5 7	5 9
25	-9 9	7 2	52 2	7 2	7 2	2 1
26	-6 8	5 3	32 4	5 3	5 3	1 8
27	-1 1	5 9	38 3	5 9	5 9	5 8
28	25 2	6 8	48 1	6 8	6 8	2 7
29	-16 7	6 6	44 8	6 6	6 6	1 1
30	-8 5	4 2	20 1	4 2	4 2	-0 9
31	2 8	7 1	49 2	7 1	7 1	2 8
32	-27 0	5 9	41 1	5 9	5 9	1 3
33	-12 0	6 4	45 6	6 4	6 4	1 0
34	-70 0	7 6	55 1	7 6	7 6	-2 0
35	-1 2	6 9	48 3	6 9	6 9	-0 7
36	-0 1	6 4	45 8	6 4	6 4	0 4
37	6 8	7 0	50 7	7 0	7 0	2 6
38	-2 2	4 2	29 1	4 2	4 2	0 0
39	0 4	7 2	53 3	7 2	7 2	4 2
Total	-1 9	5 7	42 4	6 0	5 9	2 4
	percent of displaced jobs which were held by females in 1981					
		19 2%	6 0%	20 5%	21 2%	7 0%

Key Entries are cumulative displacement rates 1982-1995 due to CBA as percentages of base-year (1981) commercial employment. A negative entry implies that jobs are created. For a key to the sectors see Table 4.

It must be remembered that the displacement of jobs reported in Tables 4 to 6 corresponds to the post-technical-change path which keeps final demand *levels* equal to those along the reference path. Once the appropriate structural and economic adjustments take place, those workers should be re-employed according to the new technological/occupational/sectoral structure implicit in the displacement patterns.

**TABLE 6**  
**Displacement by Sector and Occupation for Office Applications as a Percentage of 1981 Commercial**  
**Employment: Reference Path R and Scenario 000**

Sector	Mgrs & Admin	Clerical	Sales	Total
1	2.2	5.7	1.3	0.1
2	2.3	6.2	1.3	0.4
3	3.6	7.9	2.0	0.3
4	2.2	6.6	1.3	0.6
5	4.0	10.2	2.2	2.6
6	2.6	7.3	1.5	0.7
7	2.4	6.5	1.4	1.0
8	2.4	7.7	1.4	1.2
9	1.8	6.1	1.0	1.1
10	5.1	13.8	2.8	2.2
11	1.9	6.9	1.1	0.7
12	1.6	6.2	1.0	0.8
13	0.9	4.9	0.6	0.6
14	2.0	7.1	1.2	0.7
15	2.6	7.6	1.5	0.7
16	2.6	7.3	1.5	1.0
17	2.5	7.7	1.4	1.0
18	2.1	6.2	1.2	1.7
19	2.7	8.2	1.5	1.0
20	2.7	8.1	1.6	1.3
21	2.6	8.2	1.5	1.7
22	3.1	10.0	1.8	1.3
23	1.9	6.5	1.1	1.2
24	2.4	7.4	1.4	1.1
25	3.2	8.6	1.8	2.0
26	2.1	6.9	1.2	1.7
27	2.6	7.9	1.5	1.7
28	3.1	7.2	1.8	0.8
29	2.8	6.6	1.6	1.3
30	1.3	4.5	0.8	2.5
31	3.1	7.5	1.7	1.9
32	3.0	8.4	1.7	3.1
33	3.3	8.4	1.8	2.9
34	3.6	8.4	2.0	5.3
35	3.2	8.0	1.8	1.3
36	0.0	7.7	1.9	1.4
37	3.8	8.6	2.1	3.4
38	0.0	8.1	2.1	0.8
39	0.0	8.8	2.1	0.8
Total	3.0	7.9	1.8	2.0
	percent of displaced jobs which were held by females in 1981			
	23.2%	77.0%	41.5%	67.1%

See KEY to Table 5

#### IV 4 PERCENTAGE CHANGE IN OCCUPATIONAL STRUCTURE

Recall that a comparison of the 19xx(final) path with the 19xx(ref) path isolates the structural adjustments (occupational and sectoral) required to re-employ the workers displaced by the CBA. In particular, the sectoral/occupational employment matrix from the post-technical-change solution 1995(final) can be compared to that from 1995(ref) and/or 1981 and decomposed according to changes originating from the supply side (productivity and input changes) versus final demand changes.

The disaggregation of occupations in our model corresponds to the three-digit oc-

**TABLE 7**  
**Percentage Change in Occupational Structure: Reference Path R**

Occupation	1981 CE as % of Total	DQ	DA	DY	Inter	Net	1995 (ref) CE as % of Total
Mgrs & Admin	6.76	-18.9	8.4	33.0	-7.6	14.9	6.94
Professionals	7.35	-22.4	13.3	36.1	-11.0	16.0	7.68
Clerical	19.18	-17.1	6.9	32.6	-9.1	13.3	19.58
Sales	13.31	-3.3	-1.7	29.3	-2.5	21.8	14.59
Services	10.48	16.2	2.3	31.7	3.8	54.0	14.54
Primary	8.08	-31.1	-4.1	17.7	-5.8	-23.3	5.59
Processors	4.98	-27.7	-5.8	26.8	-7.7	-14.4	3.85
Machinists	3.36	-17.9	-8.6	34.1	-9.0	-1.4	2.98
Fabricators, Assemblers, Repairers	10.01	-20.6	-3.8	30.2	-6.8	-1.0	8.92
Construction, Transport Operatives	12.63	-15.7	-1.3	30.5	-7.4	6.1	12.06
Equipment Operatives	3.87	-26.1	-0.2	30.2	-10.4	-6.5	3.27
Total	100.00	-14.5	1.4	30.3	-6.2	11.0	100.00

Key Changes are calculated according to  $[(1995(\text{ref})/1981) - 1] \times 100$ . DQ = percent change in CE due to labor productivity (1/Q) changes. DA = percent change in CE due to material input changes. DY = percent change in CE due to final demand changes. Inter = percent change in CE due to second and third-order interaction effects—such as  $DQ \times DY$ . Net =  $DQ + DY + DA + \text{inter}$ . See table 1 for a definition of Reference Path R.

occupational classification—from which 80 occupations are included. Notice that the occupational aggregation reported in Tables 7 to 9 does not correspond to any standard classification but rather occupations which are likely to be influenced by a particular application of CBA are grouped together.

Table 7 compares the occupational structure for the R reference path solution in 1995 with that for the base-year 1981. In total, increases in labor productivity decrease the required commercial employment by 14.5% from 1981–1995. That is, 1981 output levels could be produced with 14.5% fewer workers using 1995 technology. Nevertheless, increases in final demand offset this direct negative impact such that, on average, there is an net increase in employment. When the scale (growth) effect (11% in total)<sup>12</sup> is excluded, the service-related occupations (groups I to V) increase in relative terms (that is, relative to other occupational groups) over the period 1981–1995, while the occupations related to manufacturing, construction and operating of transportation equipment (groups VI to XI) all decline in relative terms.

Table 7 reports the cumulative effect of increased labor productivity,<sup>13</sup> decreased

<sup>12</sup>The scale effect appears small. This reflects both the predicted increase in the unemployment rate from 7.5% (1981) to 10.7% (1995(ref)), using the R reference path, and the predicted slowdown in the growth of the labor force (we use a growth rate predicted in Dungan, Crocker and Garesche [6]) relative to the very rapid growth—especially in participation rates—in the 1970s. Our model was designed to analyse the implications of alternative scenarios and the relative shifts in occupations rather than levels and rates of growth. As indicated in Table 1, the evolutionary reference path (E) would result in more plausible levels.

<sup>13</sup>However, notice that—reflecting historical trends—the personal service occupations are predicted to have a fall in output per person employed.

**TABLE 8**  
**Percentage Change in Occupational Structure Specifically Due to CBA**  
**Reference Path R and Scenario 000**

Occupation	1995 (ref)	DQ	DA	DY	Inter	Net	1995 (final)
	CE as % of Total						CE as % of Total
Mgrs & Admin	6.94	-2.3	-0.1	3.9	-0.1	1.4	7.01
Professionals	7.68	2.0	-0.1	3.9	0.1	5.9	8.10
Clerical	19.58	-7.3	-0.1	4.0	-0.3	-3.7	18.80
Sales	14.59	-1.5	-0.1	4.1	-0.1	2.4	14.91
Services	14.54	0.3	-0.1	4.1	0.0	4.3	15.13
Primary	5.59	0.2	-0.1	4.0	0.0	4.1	5.80
Processors	3.85	-4.5	-0.3	3.9	-0.2	-1.1	3.80
Machinists	2.98	-39.0	-0.3	3.8	-1.4	-36.9	1.87
Fabricators, Assemblers, Repairers	8.92	-4.5	-0.1	3.9	-0.2	-0.9	8.82
Construction, Transport Operatives	12.06	0.9	-0.1	3.7	0.0	4.5	12.57
Equipment Operatives	3.27	-5.2	-0.2	3.9	-0.2	-1.7	3.20
Total	100.00	-3.4	-0.1	4.0	-0.1	0.4	100.00

Key Changes are calculated according to  $[(1995(\text{final})/1995(\text{ref})) - 1] \times 100$ . See Table 7 for key to column headings.

material input requirements, and increased demand predicted by the R baseline or reference path from 1981–1995(ref). Table 8 gives the impact of the CBA predicted by scenario 000. Therefore, adding Table 7 plus Table 8 gives the total predicted occupational shifts over 1981–1995—resulting in occupational shares as reported in the final column of Table 8. According to this reference path and technical change scenario, the total increase in labor productivity is such that 17.9% (14.5% + 3.4%) fewer workers are required to produce a given amount of output with the 1995(final) technological/occupational structure as opposed to that in 1981. However, increases in final demand are such that 34.3% more workers are required. Once the impact of change in material inputs requirements and all the interaction effects are included, the net effect is a scale increase by 11.4%.

Comparing the occupational structure of the post-technical-change solution 1995(final) with that for the R reference path (pre-CBA) solution 1995(ref), Table 8 (in the last and first columns respectively) illustrates the occupational adjustments required to accommodate the CBA (re-employ the displaced workers). For example, for this scenario, professionals increase (from 6.94% to 7.01% of the total) while machinists decrease (from 2.98% to 1.87% of the total). Some occupations (primary, personal services and construction plus transport operatives) increase not because they were directly impacted by the CBA technical change but rather due to the general increase in final demand made possible by the technical change.

In sum, relative to the R reference path, the predicted impact of this CBA on the occupational structure reinforces the historical relative decrease for processors, machinists, fabricators/assemblers, and equipment operatives, reinforces the relative increase in professionals, sales and managers/administrators, and offsets the relative in-

crease in clerical occupations. The income effects, or feedback made possible by the CBA, reinforce the relative increase in personal service occupations and partially offset the relative decrease in primary and construction trades/transport operatives occupational groups.

## V. Concluding Comments

Our strategy has been 1) to base the model in the actual data at a disaggregated level—for example, the simulations are calibrated on an annual basis to a reference or baseline path which incorporates detailed sectoral trends for both supply and demand; 2) to compile and adapt as much information as possible at a disaggregated level concerning the labor productivity *impacts* of computer-based automation, and then utilizing this sectoral and occupational information; 3) to simulate the *net* effects of CBA when the interdependencies of the economy are explicitly modeled.

Without detailed information concerning the appropriate elasticities, it is difficult to predict the speed and extent of the economy's response to the introduction of the new technology. Therefore, the probable upper and lower bounds of the feasible outcomes are computed by solving for two post-technical-change paths—one which keeps final demand *levels* equal to those along the reference path so that the potential number of displaced workers can be computed, and the other which computes the final demand and income made possible when/if all the displaced workers are re-employed using the new technological/occupational structure. Additional structure on the model provided by, for example, a theory of skill acquisition, could predict a particular transition between these two extreme post-technical-change paths

Finally, uncertainty concerning Canada's rate of adoption of the new technology (relative to other countries) has been modeled by comparing alternative *scenarios* which are determined by different diffusion rates, different degrees of dependence on foreign production of the required new equipment, and different degrees of success in export markets

Modeling potential sources of future structural change is difficult and our results are, of course, subject to the usual caveat that the predictions are conditional. In particular, they are conditional on the information available about the impact of the computer-based automation and on assumptions, for example, concerning the model's structure and the future path of exogenous variables such as the labor supply.

Nevertheless, computing the feasible range of results gives some indication of the probable numbers of new jobs required to prevent technological unemployment. The aggregate results indicate that application of available computer-based automation technologies, at historically projected rates of diffusion, does not seriously threaten the total number of jobs available. That is, the magnitude of absorption or new job creation required to prevent technological unemployment will be relatively small. For example, the aggregate results for a plausible scenario 000 indicate that the CBA modeled in this paper initiates a 0.25% (alternatively, 0.6% for scenario 200) average yearly increase in labor productivity and consequently results in a cumulative-displacement of 4.4% (alternatively, 10.7% for scenario 200) of the base-year commercial employment from 1981–1995.<sup>14</sup> Of course, these calculations of CBA-initiated displacement of workers refer to only one

---

<sup>14</sup>This compares with the new job creation associated with an increase in employment of 48% over the previous 14 year period (1967–1981) which to a large extent accommodated the demographic (baby boom) and female participation rate changes

component of the potential applications of microelectronics-based technical change. Also, the impact of CBA on non-commercial employment was not included in our model.

A further benefit of the disaggregative approach adopted here is that computing the potential size of the displacement or dislocations at a disaggregated level of detail provides an indication of the magnitude and location of possible structural unemployment (occupational and sectoral mismatches between lay-offs and new job vacancies) initiated by the CBA. The results show that the impact of the new technology will be more severe for some occupations and sectors than others. The matching of the skills and the location of the displaced jobs and those required by the new technology will be an important issue.

Most of the displacement associated with production applications occurs in sectors dealing with metal fabricating, machinery, transportation equipment, construction and primary metals, while that for office applications is concentrated in wholesale and retail trade, finance, insurance, and real estate, and in services to business management. With respect to the occupational displacement, machinists and clerical jobs are the hardest hit while computer professionals experience a net gain in jobs in some sectors. Finally, 34% of the cumulative displacement occurs for jobs which were held by females at the time of the 1981 census (our base year). However, this proportion is much higher for office applications of CBA than for production applications (67.1% versus 7% respectively).

The computer-based automation which causes the above dislocations should also initiate economic and structural adjustments which ultimately lead to the creation of new jobs. In particular, the occupational adjustments required to accommodate the CBA will for the most part follow (reinforce) historical trends. That is, the manufacturing occupations continue to decline in proportional terms while the service sector, manager/administration and professional groups continue to increase. However, the CBA offsets the historical proportional increase in clerical occupations. At considerably faster rates of adoption, the historical increase in manager/administrators and professionals is also partially offset in proportional terms.

Technical change which improves productivity also improves our standard of living—either through higher real income or an increase in leisure in the form of shorter working hours. Therefore, although the adoption of new technology can initially result in the displacement of jobs, the productivity gains should ultimately create jobs and improve national welfare. Overall, the results for our computer-based automation application highlight the importance of facilitating the structural adjustments required by technical change.

*I would like to acknowledge, with thanks, financial support from the Economic Council of Canada and assistance or helpful comments from J. Betts, R. Dell'Mour, S. Kaliski, S. Landon, A. Mansoorian, K. Newton, H. Postner, L. Wesa and R. Woodhouse. I would also like to thank I. Barrie, N. Hancock, A. Litvak, M. Manning, M. Nelson, J. Richardson, T. Warner and especially R. Beck for assistance in compiling data. The usual disclaimer applies.*

## References

- 1 Bundesministerium für Wissenschaft und Forschung, *Mikroelektronik*, Springer-Verlag, Vienna, 1981

- 2 de Boer, P M C and Donkers, H W J , On the Relationship Between Input-Output Production Coefficients and the CES Production Function, *Zeitschrift fur Nationalokonomie* 45(3), 331-335 (1985)
- 3 Canadian Machinery and Metalworking, Statistical Report on Canada's NC/CNC Machine Tools, McLean-Hunter, Toronto, 1985
- 4 DeMelto, D P , McMullen, K E and Willis, R M , Preliminary Report: Innovation and Technological Change in Five Canadian Industries, Economic Council of Canada, Discussion Paper No 176 , (1980)
- 5 Denny, M and Fuss, M , The Effects of Factor Prices and Technological Change on the Occupational Demand for Labour Evidence from Canadian Telecommunications, *J of Human Resources*, Spring, 1983
- 6 Dungan, P , Crocker, D and Garsche, G , The Ontario Economy 1982-1995 Volume 2, Ontario Economic Council, Policy Studies Series, 1983
- 7 Dungan, P and Younger, A , New Technology and Unemployment A Simulation of Macroeconomic Impacts and Responses in Canada, *J of Policy Modeling* 7(4), 595-619 (1985)
- 8 Evans Research Corporation, Annual Revenue Survey of the Top Computer Companies in Canada, 1984, Toronto, 1985
- 9 Evans Research Corporation, The Canadian CAD/CAM Market, Research Study No 65, Toronto, 1985
- 10 Globerman, S , The Adoption of Computer Technology by Insurance Companies, a study prepared for the Economic Council of Canada , 1984
- 11 Howell, D R , The Future Employment Impacts of Industrial Robots An Input-Output Approach, *Technol Forecast Soc Change* 28, 297-310 (1985)
- 12 Hunt, H A and Hunt, T L , Critique of The Impact of Automation on Employment, 1963-2000 by Leontief and Duchin, mimeo, 1984
- 13 Hunt, H A and Hunt, T L , Human Resource Implications of Robotics, The W E Upjohn Institute for Employment Research, 1983
- 14 Leontief, W and Duchin, F , *The Future Impacts of Automation on Workers*, Oxford University Press, New York, 1986
- 15 McCurdy, Thomas H , Some Employment, Income and Occupational Effects of Microelectronic-Based Technical Change A Multisectoral Simulation for Canada, *J of Policy Modeling* 9(2), 269-297 (1987)
- 16 McCurdy, Thomas H , Employment, Income, and Occupational Effects of Computer-Based Automation in Canada, Economic Council of Canada, Discussion Paper No 340, 1987
- 17 Neary, J P , On the Short Run Effects of Technological Progress, *Oxford Economic Papers*, June, 1981
- 18 Office of Technology Assessment, Congress of the United States, Computerized Manufacturing Automation Employment, Education, and the Workplace, 1984
- 19 Office of Technology Assessment, Congress of the United States, Automation of America's Offices, 1985
- 20 Ontario Ministry of Industry, Trade and Technology, Innovation and Technology Division, The Market for Flexible Automation Equipment in Ontario, 1985
- 21 Ontario Task Force on Employment and New Technology, Report, Queen's Printer for Ontario, Toronto, 1985
- 22 Organization of Economic Co-operation and Development, Microelectronics, robotics and jobs, Information and Computer Communication Policy Series No 7, 1982
- 23 Pilorusso, F , The Labour Displacement Implications of Microelectronics Technology in Automotive Assembly Plants a case study, Ontario Ministry of Labour, Research Branch Report No 23, 1982
- 24 Policy Studies Institute, Microelectronics in Industry An International Comparison Britain, Germany, France. Report No 635, London, 1985
- 25 Roessner, J D , Forecasting the Impact of Office Automation on Clerical Employment, 1985-2000, *Technol Forecast Soc Change* 27, 203-216 (1985)
- 26 Rumberger, R W and Levin, H M , Forecasting the Impact of New Technologies on the Future Job Market, *Technol Forecast Soc Change* 27, 399-417 (1985)
- 27 Schmoranz, I , Macroeconomics and Microelectronics—Results of a Study on Applications, Diffusion and Effects in Austria, *Prometheus* 2(2), 167-175 (1984)
28. Siedule, T and Leckie, N., Occupational Demand Estimation and Projection, Economic Council of Canada, Discussion Paper No 229, 1983

- 29 U S Department of Commerce, Improved Deflation of Computers in the Gross National Product of the United States, Bureau of Economic Analysis Working Paper 4, Washington, 1985
- 30 Werneke, D., Microelectronics and office jobs the impact of the chip on women's employment, International Labour Organization, A WEP Study, 1983
- 31 Whitley, J D and Wilson, R A , Quantifying the Employment Effects of Micro-Electronics, *Futures*, December, 1982