Appendix C
Papers Prepared for Workshop

The following papers were prepared as background materials for the OTA Labor Markets and Industrial Relations Workshop which was held July 27, 1982. ***Their content and conclusions are the sole responsibility of the authors and do not necessarily reflect the views of OTA.***

1. "The Economics of Technical Progress: Labor Issues Arising From the Spread of Programmable Automation Technologies," by Eileen Appelbaum.
2. "Assessing the Future Impacts on Employment of Technological Change: An Input-Output Approach," by Faye Duchin.
3. 'The Effect of Technical Change on Labor," by Louis Jadobson and Robert Levy.
4. "Programmable Automation: Its Effect on the Scientific-Engineering Labor Market," by William N. Cooke.
5. "Technology and Labor," by Markley Roberts.
6. "Labor-Management Relations in an Era of Programmable Automation," by William'N. Cooke.

THE ECONOMICS OF TECHNICAL PROGRESS: LABOR ISSUES ARISING FROM THE SPREAD OF PROGRAMMABLE AUTOMATION TECHNOLOGIES

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July **27, 1982**

One of the specific objectives of this workshop is to place alternative analytic methods which may be used to make inferences about programmable automation technologies and labor market issues in perspective. A second objective is to specify the information requirements associated with the formulation of appropriate policies and legislative initiatives. The two objectives are related in that the choice of variables for study as well as the specification of the behavioral relations among them is dictated by the system of analysis that is utilized. My remarks are directed to the second set of questions which this panel will be considering, subsumed under the heading, "To what extent are the production and use of programmable automation likely to result in unemployment of current workers and job displacement?" My view is that an adequate system of analysis is indispensable to an evaluation of the questions raised in this section and to the design of studies capable of providing reliable information.

The first section of this paper is a critique of the standard economic analysis of technology and employment. This view probably exercises some influence in the policy community and elsewhere. Its conclusions are remarkably sanguine. They may or may not prove to be true; but the analysis itself is faulty and the conclusions are not supported by it. I will keep my comments brief, and will limit them to demonstrating the most critical weaknesses of this approach. In the next and most important section I will proceed to the constructive task of developing the economics of technical progress to encompass the issues of interest to this panel. The analysis presented in this section will, I believe, make clear the existence of important relationships that are not otherwise obvious, and will provide qualitatively new insights in the analysis of the employment issues. The final section will indicate the kinds of studies that will best serve to increase our knowledge of the effects of this latest round of automation on workers, jobs, and employment.

Critique of the Standard Economic Analysis of Technology

The analytical methodology employed by economists to analyze the effects of the introduction of robots on wages and employment of workers in the affected industries and upon employment generally

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tends to trivialize what is a complex question, and offers little policy guidance. This does not ***appear to*** create any difficulties, mainly because the analysis leads economists to the conclusion that, apart from a short-term need for retraining, workers face no problems. Thus, standard analysis suggests that robotics: 1) will have a positive impact on wage levels, 2) will probably tend to reduce rather than increase unemployment in the long run, and 3) will stimulate total employment even in the industry introducing the robots.[1] The analysis on which these conclusions are based can only be characterized as glib and superficial.

In analyzing the wage and employment effects of introducing robots, a typical approach taken by economists is to present a hypothetical situation. One typical presentation compares the case in which a widget factory adds one additional worker to its existing production line and increases output by 4 units a day to the case in which the firm buys several robots and hires one additional worker to oversee them, thus increasing output by 10 units a day. At **$20** per widget, the author concludes that the value of a worker's marginal product has increased from $80 to **$200** and that the firm, which previously would have been unable to pay any worker more than **$80** will now be forced by competition to pay this new worker something near the $200 figure. This type of example, though common, is peculiar; and the argument behind it is logically incorrect.

It is strange that in this example the robots do not replace any previously employed workers (welders, painters, machinists, etc.), but are simply added to an existing production process. It's an unusual technology, indeed, that simply adds two or three robots to an existing process without materially affecting that process. As no workers have been replaced, utilization of the robots simply ***increases*** employment by one skilled worker because the robot requires maintenance and oversight. Economists making this argument sometimes conclude that the worker hired will be a skilled worker. Now, robot-fixer may be a more skilled job than painter or welder, but robot-minder is not. With only two or three robots, the firm is likely to contract out for robot maintenance, increasing employment in the contracting firm by considerably less than one skilled worker. The worker hired by the firm using only two or three robots is more likely to be a relatively unskilled adjunct to the robot. By making the robot overseer both robot-minder and robot-fixer, this approach manages to evade entirely the issues involved in the fact that some skills will be downgraded even as others are increased.

Moreover, the argument is logically incorrect. In going from the first case to the second, an increase of capital (two or three robots) as well as an increase of labor (one robot-fixer) has been slipped into the example. Capital and labor have both increased, and consequently it is not possible to speak of an increase in the marginal product of labor. Nor can the firm afford to use the total increase in productivity to increase wages. What this argument appears to ignore is that with an increase in wages for the newly hired worker from $80 to $200, the **rate of profit on capital has decreased. The *amount*** of capital has increased by two or three robots, but all the increase in output has gone to pay the wages of the robot-fixer. Consequently, gross profits are unchanged. As a result, the ratio of net profits to capital (the rate of profit on capital) has decreased. An even more serious consequence is that, with gross profits unchanged, the firm will be unable to amortize the new robots. How will it replace them as they wear out'?

Economists sometimes use oligopolistic industries like auto and steel as illustrative examples in considering what will happen to the price of, and demand for, output. In these examples, price and quantity sold of steel and cars are determined by impersonal market forces. Auto and steel firms exercise no control over market price and, in particular, they do not view price as a strategic variable which they can manipulate to restore profitability after the introduction of robots. Nor are steel or auto workers capable of bargaining for higher money wages as their productivity increases. Thus, the introduction of robots reduces production costs, increases supply, and ultimately causes prices to decline and the quantity demanded to increase. The problems with this analysis when applied to industries like steel and autos are myriad. If firms exercise market power to increase profit, or workers bargain for wage increases, or the new technology requires greater investment, or the new technology is likely to become obsolete in a short time as robots become more sophisticated and hence has higher amortization costs, then the decline in production costs will be damped, supply need not shift very much, prices need not fall very much, and the quantity demanded need not be much affected. Real wages and / or profits will increase and demand may very well be affected, but simple textbook models of supply and demand are not sufficient for analyzing industries that are highly unionized, capital intensive, and in which firms are able to exercise market power. An alternative analysis which poses very different questions and possibilities, is a prerequisite to research.

[1]See, for example, Richard K. Vedder, "Robotics and the Economy, " a staff study prepared for the Joint Economic Committee, Congress of the United States, Mar. 26, 1982 (Washington, D. C.: U.S. Government Printing Office, 1982).

On one point standard economic analysis is correct: there is no stopping the introduction of robots. Even if it should turn out that employment is adversely affected and the rate of profit on capitaJ is approximately the same after the introduction of robots as it was before, firms cannot avoid trouble by never adopting the new technology. So long as some firms (in this case, Japanese or European firms) are going to introduce the new technique, U.S. firms will have to do likewise or find they are unable to compete in world markets. In the absence of competition, firms have sometimes delayed the introduction of cost saving techniques to protect the value of existing capital. In the presence of competition, delay risks loss of sales and, hence, of jobs. U.S. firms will ultimately have to adopt robotics and related technologies. If they do so later rather than sooner, they will lose whatever advantages accrue to having been among the leaders.

The Economics of Technical Progress: Labor Issues Arising From the Spread of Programmable Automation Technologies*

Programmable automation technologies are introduced in order to reduce manufacturing cost per unit of revenue. That is, as a result of robotics, firms expect their net receipts from a given outlay to be higher than they would have been otherwise. A successful innovation reduces costs—saving labor cost, or saving capital cost, or expanding the resource base and thus saving resource cost. An innovation may be worth making even if it raises one element of cost provided that it reduces other elements more. Thus, programmable automation technologies will be introduced because they reduce labor costs by increasing output per man-hour or by allowing the substitution of cheaper for higher paid labor, or because they reduce amortization charges by embodying major advances in technique in new plant and equipment, thus reducing the risk that the capital stock will become prematurely obsolete and extending its probable useful life. Such changes in technique maybe cost saving even if they increase capital costs. The effect of the new technologies on wages and employment will vary, however, depending on whether they are capital saving or capital using. Capital costs are increased, and the new technique may be characterized as ***capital using***, if the firm requires higher levels of investment in order to achieve a given increase in capacity. It may be characterized as ***capital saving*** if less investment will achieve a given increase in capacity, and it may be characterized as neutral if the amount of investment required to achieve a given increase in capacity is the same with the old and new techniques.

Whether they are capital using or capital saving, programmable automation technologies are labor saving. A saving in labor cost may be due to an increase in output per man-hour with the type of labor (i.e., the distribution of skill levels) unchanged, or it may be due to the substitution of less skilled labor for more skilled. It will, thus, be necessary to consider several cases.

Wage and Employment Effects

Programmable automation technologies are likely to spread throughout the manufacturing sector, though they may have fewer applications in some industries than in others. Consider first what will happen if these technologies are capital saving (or neutral) and, in addition, are labor saving due to an increase in output per man-hour and not due to the deskilling of work. If money wage rates are unchanged following the introduction of robots and related technologies, then the effect of these innovations depends on what happens to the price of manufactured goods. If the price of these products is unchanged, the net profit per unit of output and net profit per unit of capital will be increased. Real wages will be unchanged. If the prices of these products decline, as a result perhaps of the strength of foreign competition for the domestic market, then real wage rates will rise. The increase in real wages will be greatest when competition is strong enough to force prices down to the point at which net profit per unit of capital is the same after the change in technology as it was before the change. Lesser price decreases imply an increase in the rate of profit and smaller increases in real wages. An alternative scenario is one in which money wage rates increase in line with productivity advances so that unit labor costs are constant while prices are constant or increase. Again, so long as competition is sufficient to assure that prices increase by less than wages, real wages will increase. The extent of the increase in real wages will depend on the strength of competition in product markets, which limits the increase in the rate of net profit on capital following the introduction of the new technique. Provided that competition in product markets is not entirely absent, ***real wages of manufacturing workers will increase following the spread of programmable automation techniques if the proportion of skilled manufacturing jobs does not decline.***

The effect on employment in manufacturing depends, in the first instance, on what happens to effec-

*This argument owes much to Joan Robinson, "Notes on the Economics of Technical Progress," *The Generalisation of the General Theory and Other Essays* (New York: St. Martin's Press, 1979 (1952)). The importance of capital saving technology in economic development was suggested to me by Professor Thomas Hughes of the University of Pennsylvania.

tive demand for manufactured commodities and capital goods. To maintain a given level of manufacturing employment, demand for manufactured goods (including robots) must increase in the same proportion as output per worker. If the new technology is capital saving (or neutral), then the increase in capital goods required to maintain a given level of employment will be less than proportionate (just proportionate) to the increase in output forthcoming from that employment. Then the ***increase in demand (including export demand) for manufactured commodities will have to increase more rapidly than (at the same rate as) output per head in order to maintain employment constant.*** If effective demand for manufactured products does not grow apace, technological unemployment in manufacturing will result. Keynesian demand management policies may or may not be capable of increasing effective demand sufficiently to prevent unemployment in individual industries—it depends on the extent to which the new technology increases output per worker. Given worldwide excess capacity in steel production, for example, reliance on demand management alone is insufficient to restore the U.S. steel industry's employment to its 1979 level, even after cost saving robots are introduced.

A reduction in the workweek with no reduction in weekly income is an alternative means of maintaining employment in manufacturing. The question that arises is whether this can be done without raising unit labor costs or reducing real weekly wages. If the new technology is capital saving or neutral and doesn't reduce the proportion of skilled jobs, the answer is "yes." ***With output per worker increasing and the ratio of investment to output constant or declining, it is always feasible to reduce the workweek without a reduction in weekly income or an increase in price.*** The increase in labor productivity in an industry may be shared between a slower increase in weekly income and a reduction in the workweek for workers in that industry. * A reduction in the workweek under these circumstances is always possible. There are at least two reasons, however, why it may not be practical. First, a shorter workweek is only possible if prices of the industry's products do not decline. In the face of international competition for domestic markets, it may not be possible to meet this condition. Second, consider what happens when some manufacturing industries are better able than others to utilize the new technologies, and thus achieve much greater increases in productivity. If the standard workweek in manufacturing is reduced, the reduction is likely to apply to all manufacturing industries, including those with slower productivity gains. Labor costs and prices in industries where productivity improves less must rise as a result of the reduction in the workweek. If the products of such industries are capital goods, they will raise the final price of the outputs of the technically progressive industries in which they are used, possibly making them less competitive in world markets. In any event, the increase in the price of output of industries where the new automation technologies are less applicable retards the rise in real wages of workers. ***Thus, a reduction in the weekly hours of manufacturing workers with no reduction in weekly income can most easily be undertaken if 1)programmable automation technologies prove to be capital saving or neutral, 2) real wages of workers rise because money wages increase in line with productivity increases while prices remain constant (and not because money wages remain constant while prices decline), and 3) the technologies are widely spread among manufacturing firms and not much more highly concentrated in some than in others.***

If programmable automation technologies are capital using rather than capital saving or neutral, the discussion of the effect on real wages has to be modified somewhat. Again, if money wages and prices are both unchanged, net profit per unit of output will increase. Whether any increase in the rate of profit on capital and/or real wages is possible depends on whether the increase in the amount of capital required per unit of output and in net profit per unit of output are proportionate. That is, it depends on whether the saving in labor cost is completely offset by the increase in capital costs. ***If it is not entirely offset, then provided competition in product markets is not entirely absent, real wages of labor will rise.*** The increase, however, will be more moderate than if the technology were capital saving or neutral. The reason for this is straightforward: If the new technologies are capital using, a larger share of gross output will be required for amortization. The increase in net output available to be divided between increases in real wages and in the rate of profit is consequently smaller. For the same reason, the possibilities for trading off increases in real wages for a shorter workweek are more limited.

● The following example may clarify this point. Consider a firm that employs 10 workers at 40 hours a week and produces 100 widgets a week. The workers are paid $1.00 an hour and the widgets are priced at $5.00 each. Each worker earns $40 per week. The total wage bill is $400 and total profits are $100. Now suppose a capital saving advance in technology is introduced that increases output per worker by 50 percent, and that wages also rise by 50 percent to $1..50 an hour. Suppose that demand for widgets increases, but not enough to maintain employment of all 10 workers. Suppose that demand for widgets increases to 120 a week. Following the advance in technology, this output can be produced with only eight workers. The total wage bill is now $480 (eight workers working 40 hours at $1.50 an hour).The wage bill has increased 20 percent. With no increase in price, total profits will increase to $120, also a 20-percent increase. The eight workers are employed a total of 320 hours a week. If a decision is made to maintain employment by reducing the workweek, the 10 workers will each work a 32-hour week. At $1.50 an hour, each worker will earn $48 a week. The workweek has decreased, labor costs have not increased, real weekly wages have increased (though more slowly than they otherwise would have), and the increase in profits is unaffected.

Even when demand for manufactured goods grows in line with the growth of output per worker, a capital saving technology will not directly increase employment in the capital goods industries. A capital using technology, however, may have this effect. With investment requirements higher, whether employment will increase in the capital goods industries depends on whether these industries have also introduced labor saving technologies as they shifted from the production of ordinary to programmable automation technologies.

An important motive for the decision of firms to introduce capital using techniques is that such techniques may substitute machinery for skill, reducing the skill component of the task, and making possible the substitution of lesser skilled machine-tenders for more highly skilled craftsmen. * Such developments in technology save labor costs by allowing firms to substitute cheap labor for more expensive, and bring us to the third case which must be considered. This type of technical change is, perhaps, more invidious than a change which saves labor by increasing output per worker without reducing skill requirements. One reason is that even if aggregate demand policies could be devised to maintain reasonable full aggregate employment levels, skilled manufacturing workers would be displaced by less skilled workers. If the wages of skilled workers do not then decline substantially, the new technique will diffuse through the industry, effectively displacing the skilled workers. A substantial decline in wages of skilled workers might check the spread of the new technique, allowing both techniques to operate side by side. This outcome, however, would probably require a decline in the wages of skilled workers sufficient to nearly eliminate the wage differential between skilled and unskilled workers. Unlike changes in technology that save labor costs by increasing output per worker, changes in ***technology that save labor costs by enabling firms to substitute cheap, unskilled labor for more highly skilled workers do not increase real wages.*** Whether the rate of profit on capital increases or not, net profit as a share of output and amortization will both increase as a result of the introduction of a more capital using technique. Given the overabundance of workers available for less skilled jobs in the U.S. economy, and their lack of union organization and bargaining strength, it is unlikely that real wage rates of less skilled workers will increase. Union organization of these workers could change this, of course, by capturing for the less skilled employees some part of the cost saving associated with the elimination of more highly skilled jobs. Otherwise, average wage rate in manufacturing will be reduced and the rate of profit increased. In any event, high wage jobs will have been eliminated.

This raises a related issue. As we have just seen, firms in an industry can improve their cash flow position (net profit plus amortization) by adopting a technique that is capital using but saves labor cost by allowing the substitution of less skilled labor for more skilled. For this reason, they may choose such a technique in preference to an alternative available technology that saves labor cost by increasing output per worker without reducing skill levels since such techniques, in general, increase real wages. Such a choice, however, may have serious negative ramifications for further technological change 10 or 20 years in the future. These negative impacts may affect the competitive position of such firms vis-a-vis foreign competitors who have chosen not to reduce the proportion of skilled workers employed. A hypothetical example, which Peter Albin of CUNY suggests may not be so far from the truth, may serve to illustrate this point. Suppose that when a U.S. firm puts in a robotic installation, it replaces as many as six master machinists with one programmer plus three entry-level people whose function is to "load and unload," keeping things lined up for the robots. In Japan, on the other hand, let us suppose that master machinists are retrained and prepared for positions as machinist / programmers. The machinist's job is transformed but not downgraded, and the machinist is ready for future changeovers. The initial cash flow advantage is gained by the American firms which have a less skilled and lower paid labor force. However, the man / machine configuration in U.S. firms is more permanent, less flexible. In the absence of skilled master machinists, the opportunities for learning by doing are severely curtailed. The Japanese in this example, because they retain their master machinists, need to build less into the machine, can design less immutable man / machine configurations, have enhanced opportunities for learning by doing, and have increased opportunities for continuous technological change. Longrun competitive advantage would rest with the Japanese. This example suggests that the substitution of less skilled workers for craft and highly skilled workers, as a means of holding down costs and increasing profits in the near future, may be myopic. In the longer period, it could have serious implications for international competitiveness and manufacturing employment.

*** Such a development has occurred in the last decade in the baked goods industry. Bakers continued to be classified among craft workers although, increasingly, the baker's task has become one of minding, measuring, and mixing machines, Cheap labor, often female, has been substituted for highly skilled craft labor as mechanization increased and the job was deskilled.**

Changes in Aggregate Employment Outside Manufacturing

Changes in technology that involve the deskilling of tasks have a deleterious effect on the employment possibilities of skilled manufacturing workers, while those that increase output per worker raise the specter of technological unemployment. Such unemployment will materialize if growth in demand lags behind productivity growth. In an open economy, in which imports supply some part of the domestic market, growth in demand at home and abroad for domestically produced manufactured products will have to outstrip the productivity gains just to maintain employment constant. Otherwise, as seems likely, employment in U.S. manufacturing will decline. The question, then, is whether employment in nonmanufacturing sectors of the economy will expand and absorb displaced workers as well as new labor force entrants who would previously have found skilled and semiskilled manufacturing jobs.

Economists are used to thinking of increases in productivity as increasing real income and spending, thus increasing demand for services and other products, as well as employment in the industries producing them. It happens, however, that it matters whether the increase in real income is an increase in real wage rates or an increase in net profit. An increase in net profit results in an increase in business saving, and sets up the conditions for a cyclical decline in employment. Moreover, the marginal propensity to save and to consume imports is higher among those income groups receiving dividends than among wage earners, again with negative implications for U.S. employment. Some part of the increase in net profits will increase demand for producer services (e.g., advertising, financial, architectural, or computer services), so that output of this sector will increase.

An increase in real wages, on the other hand, is likely to generate an increase in demand for the full range of consumer goods and services. Output will increase, but the effect on aggregate employment is more uncertain. Two cases need to be considered: the case in which technology in nonmanufacturing firms is essentially unchanged, and that in which labor saving programmable automation technologies spread through the nonmanufacturing sectors as well.

Suppose that the application of programmable automation technologies is confined to the manufacturing sector and does not spread to the two other broad sectors of the economy—other goods producing industries (agriculture, construction, and mining) and nongoods producing industries broadly construed as the service sector. Price declines for some manufactured goods, as a result of the increase in output per worker, are likely—in clocks, calculators, home computers, etc. Typically, however, real wages of manufacturing workers and profits of manufacturing firms will increase as a result of increases in money wages in line with productivity and prices that remain largely unchanged, perhaps creeping upward slightly. * With prices largely unchanged, real wages of nonmanufacturing workers are also unchanged. As manufacturing workers' spend their higher real incomes, demand for nonmanufactured goods will increase. The higher incomes (gross profits and total wage bill, though not wage rates) generated in these sectors again increase demand for manufactured goods, other goods, and services. Since ***existing technologies in the service sector have a much higher ratio of labor to "output," growth in services and consequently in service sector employment could possibly maintain aggregate employment, increasing the share of service jobs.***

The employment outcome is far less optimistic if unionized workers in construction, mining, transportation, and the public sector, concerned over the decline in their relative real wage position, bargain for higher money wages. The resulting rise in prices, especially of housing, will slow the increase in real wage rates due to the advance in technology in manufacturing, and hence will retard the increase in employment generated by expenditures out of increased wage income. Moreover, with prices rising the already low real wages of nonunionized workers in retail trade and health services, and of many of the clerical workers found in the service sector, will decline, The resulting change in relative output prices may stimulate demand for these services, resulting in a disproportionate increase in such low paying jobs.

It is not realistic, of course, to assume that programmable automation technologies will be limited to the manufacturing sector. In particular, the spread of distributed data processing in offices has already begun and should be well under way by 1990. Automation in manufacturing had progressed far even before the introduction of robots and related technologies. Reliable estimates of productivity growth as a result of these new techniques are not available, though the guess that is bandied around is that between 4 and 9 percent of the work in manufacturing is suited to such automation. * * The effect on employment will be less than 4 to 9 percent since robot support staff—maintenance and repair personnel, programmers, and machine-tenders-will be required. Productivity might increase by as much as 6 percent. These are only guesses,

● Such was approximately the case in the United States from 1950 to 1964. If there are price shocks from increases in resource prices (oil, food, etc.), a wage-price spiral will upset this pattern of real wage gains.

"h-i the Carnegie-Mellon survey, responding firms placed it at 8 percent. Like most of our information on the subject, this is little more than a guess.

of **course, but that future productivity gains** in manufacturing will approximate current gains in a technologically progressive sector like communications, does not seem entirely unreasonable. Unlike manufacturing, automation in offices is a qualitatively new experience. Mechanization, in which machines supplement the input of workers, has occurred steadily with the introduction of typewriters, electric typewriters, and word processors as well as other business machines. But office automation, in which machines take over entire worker functions and drastically alter job content for the remaining workers is a recent phenomenon. Gradual gains in clerical productivity since 1948 may, within the decade, be replaced by rapid advances in output per worker. Again no reliable estimates of the potential spread of office automation have been made for the United States. European observors[3] suggest that **30** to **40** percent of clerical work may be suitable for automation, with the impact on employment in the **20-** to 30-percent range. These guesses (and I emphasize that they are only guesses) suggest an increase in labor productivity in the office of about **25** percent. Even if these guesses are too high by a factor of 2 or 3, they suggest the severity of the technological unemployment problem that may emerge if programmable automation technologies spread through both manufacturing and nonmanufacturing sectors. With so small a fraction of clerical workers unionized and so large a percentage of them women, clerical workers are likely to reap but few of the gains of their higher productivity directly. Major employers of clerical workers—insurance companies, accounting firms, advertising agencies, computer service firms, law firms-may lower their rates, raising real incomes generally and stimulating demand for their services. Alternatively, net profits will increase if rates are unchanged. In either case, the ***rapid growth that has characterized clerical employment in the last decade is likely to slow, further compounding the problem of providing jobs for new labor force entrants.***

Rapid Technological Change and Investment

One other aspect of the relationship between implementation of new technology and employment should be briefly noted. Older plant in manufacturing industries, auto and steel perhaps, may have been rendered obsolete more quickly than anticipated. Certainly the step up in the pace of automation has generated a major increase in demand for office equipment. During the period of the changeover to programmable automation and microprocessor-based technologies, a period which may last 10 to **20** years while more versatile robots and software for office and other applications are developed, investment in the capital goods required to replace manufacturing plant that has had to be prematurely scrapped or to increase capital-to-labor ratios in offices will generate employment. High capital requirements as offices switch to electronic equipment and manufacturers use computerized machinery implies employment growth over the next two decades in industries supplying advanced capital goods. If these goods are produced in U.S. plants, growth in manufacturing jobs in these industries will, during this period, partially offset the loss of manufacturing jobs in industries where the new technologies are implemented. ***The full impact of technological unemployment will not be felt until 2000.*** The unknown here is the extent to which this market, both domestic and international, will be supplied by firms located in the United States. The Japanese lead in computerized manufacturing is substantial and its greater experience in successfully producing and using robots gives it an advantage in future sales of these machines. The Yamazaki Machinery Works reports more than 300 serious inquiries from U.S. companies alone.[4] American firms are better situated in the markets for electronic office equipment, home computers, electronic toys, but competition from Japan, West Germany, the Netherlands, and France is intense.[5] The growth of U.S. multinational corporations (MNCS) is a further threat to the future of U.S. manufacturing jobs in these industries. The widely scattered manufacturing operations of semiconductor firms are a case in point.

Multinational Corporations and Employment

The existence of MNCS further complicates the analysis of job loss due to changing technology. When firms were national entities and not multinational concerns, it was increasing wages of skilled workers within a country that motivated firms to seek new techniques that save labor cost by substituting less skilled for more skilled workers. The existence of MNCS with affiliates in low wage areas means that such firms have an incentive to invest in techniques that substitute less skilled Third World workers for American workers so long as the wage differential between the two groups of workers exceeds some minimum. When transportation costs for bulky products manufactured in the Third World were high, even a substantial wage differential might not have induced U.S. firms to move their fabricating operations abroad. Progressive advances in microminiaturization, lightweight materials, and transportation technology have changed that.

[3] "The Job-Killers of Germany," *New Scientist*, June 8, 1978.

[4] *New York Times*, Dec. 13, 1981, sec. 3.

[5] *Business Week*, Dec. 14, 1981, pp. 39-120 and Dec. 21, 1981, pp. 52-54.

The ability of the developing countries to compete in the production and sale of manufactured products to the United States is only partially the result of indigenous economic development. It results as well from the growth of U.S. multinationals. The unique advantage of the MNC in comparison with national firms is its transnational ability to combine labor and material resources in the host country with technology and administrative capabilities developed in the home country. Because labor costs in less developed countries are so much lower than labor costs in the United States the possibility exists that increasing North-South trade will result in increasing specialization in production within countries with the developing countries specializing in the production of an increasing number of manufactured products. The debate over whether steel production, like black and white televisions, should be phased out in favor of imports emphasizes the immediacy of this concern. Leaving aside the issue of whether the United States should view industrial structure as an object of policy, formulating economic policies designed to achieve some structural outcome, let us consider the implications for employment as technology advances. The export of manufacturing jobs outside the United States means that productivity gains will be realized elsewhere. How much of the increase in productivity will go to increase the real wages of local workers in American-owned plants overseas is uncertain. Even if the MNC captures the entire productivity increase, it may or may not reduce the price of the product in U.S. markets. A price reduction would, of course, mean an increase in real income in the United States, which would raise demand for output and increase employment in this way. The magnitude of the effect would depend on how much of the increase in productivity the MNC keeps in the form of retained earnings (to finance expansion of its foreign subsidiaries as well as, or in place of, its American operations) and how much it passed along in the form of lower prices.

Service Sector Jobs and the Quality of Employment Opportunities

The analysis of the previous section focused on the effects of programmable automation technologies on real wage rates and on *aggregate* employment. To discuss the qualitative aspects of service sector employment growth requires that we turn our attention to how labor markets are currently structured. To begin, I want to consider the familiar thesis that investment in human capital will enable the service sector to continue expanding, so much so that it will easily absorb the workers displaced from manufacturing.[6] This hypothesis, relating economic growth to human capital formation, is a simple extrapolation of the findings of "growth accounting." In growth accounting, past economic growth is broken down into its component sources—quantity and quality of labor inputs, quantity and quality of capital inputs, The great accomplishment of growth accounting has been the identification of the increasing educational attainments of the labor force as one of the quantitatively most significant sources of growth in output per worker between 1929 and 1969.[7] However, growth accounting provides no theory to explain the nature of the relationship between the quality of labor inputs and economic growth. All that can be said on the basis of growth accounting is that investment in human capital and economic growth both proceeded at an impressive rate during the period following 1948. It is incorrect to infer that increased schooling caused economic growth from the association between educational attainment and the growth in gross national product (GNP). Service sector employment has also grown substantially during this period, though again cause cannot be inferred from correlation. In considering the ease with which displaced manufacturing workers can be absorbed by a growing service sector, two points need to be addressed. The first relates to the sex-labeling of jobs in the U.S. economy, and the second to the quality of service sector jobs.

Much of the expansion in service sector employment in the 1970's was in jobs for which women are the preferred labor force—retail sales including restaurants and fast food establishments, and health services. These are jobs that typically employ women at wages below the average in manufacturing, and that provide short hours, few fringe benefits, and little opportunity for advancement. Clerical employment was another important area of job growth. Here, again, women are the preferred labor force. Though the jobs are more varied in terms of responsibilities, opportunities, and wages paid, they are nevertheless among the poorest paid and least prestigious of the white-collar occupations. The shift to service sector jobs has largely been a shift away from jobs employing male workers and toward jobs employing females. Despite the growth

[6] Eli Ginzberg and George J. Vojta, "The Service Sector of the U.S. Economy," *Scientific American* 244, March 1981.

[7] The development of growth accounting is best exemplified in the work of Edward F. Denisen, The *Sources of Economic Growth in the United States and the Alternatives Before Us* (New York: Committee for Economic Development, 1%2); Why *Growth Rates Differ: Postwar Experience in Nine Western Countries* (Washington, D. C.: The Brookings Institution, 1%7); *Accounting for United States Economic Growth,* 1929-69 (Washington, D. C.: The Brookings Institution, 1974); *Accounting for Slower Economic Growth: The United States in the 1980's* (Washington, D. C.: The Brookings Institution, 1979).

in employment, high unemployment rates for women persisted throughout the decade, suggesting there was no shortage of female workers available to take such jobs. Had manufacturing employment decreased by nearly a million jobs during the last decade instead of having increased by that amount (measured from its peak in 1969 to its peak in 1979), with most of the displaced workers men, it is unclear for which service sector jobs they might have been retrained.

My second point is that the growth of service sector jobs has meant an increase in both good and poor jobs. It is evident that the U.S. labor market is segmented into a primary labor market segment in which most of the "good" or "acceptable" jobs are located, and a secondary segment in which most of the "poor" jobs are to be found.[8] A further distinction can be made between autonomous primary segment jobs (professionals, like doctors, lawyers, and professors, or craftsmen like plumbers, electricians, carpenters) and subordinate primary sector jobs (mail carriers, city transit drivers, steel workers, etc.). The difference between a subordinate primary sector job and a secondary sector job is sometimes based on worker skills and sometimes on nonskill-related job characteristics. The better jobs are those in which the employer values steadiness and low turnover and is willing to reward tenure on the job with promotions and higher pay, or in which the employee is represented by a union that has won decent wages, a pay scale that rewards seniority, and protection against arbitrary treatment. Many of the subordinate primary sector jobs available for male workers are to be found in the goods producing sector of the economy, where workers have more union representation than in the service sector. This is probably the basis for the casual observation that changes in technology and the shift to service sector employment is eroding the middle of the job distribution, making the labor market more starkly two-tiered with good jobs at the top, poor jobs at the bottom, and shrinking opportunity in the middle.

The growth of the service sector has provided both good jobs and poor ones. Producer services (advertising, architecture, law, management consulting, computer, financial) now account for 19 percent of GNP, and firms in this industry have been a major source of good jobs.[9] This observation is confirmed by a Bureau of Labor Statistics (BLS) study of the computer and data processing services industry (SIC 7372 and SIC 7374).[10] This industry currently employs nearly 350,000 workers and is one of the rapidly growing business services.[11] The BLS survey found that approximately 37 percent of the nonsupervisory employees in this industry are highly paid professional or technical workers, many of them computer systems analysts, computer operators, and computer programmers. At the same time, however, the survey found that office clerical employees account for another 32 percent of employment in this industry. Two-fifths of the office clerical employees are key entry operators earning $135 to $175 (Class B) or $150 to $205 (Class A) in 1978. If we calculate their hourly wage on the basis of a 35-hour week, they earned between $3.86 and $5.86 an hour. By comparison, average wages in manufacturing in 1978 were $6.17 an hour. The point is that service sector employment, like employment in the U.S. economy generally, is two-tiered. The growth of this sector has meant an increase in professional, technical, and managerial jobs at the top; but it has also meant an increase in clerical, sales, and nonprofessional service jobs at the bottom. In particular, poorly paying jobs in health services have been a major source of employment growth in the 1970's.

The number of good jobs has grown but, since 1970, it has failed to keep pace with the supply of college graduates. Employment prospects have deteriorated substantially since the 1950's and 1960's.[12] The result has been a credentials inflation in which a college degree is now a prerequisite for many jobs which could be done or previously were done by workers with a high school education. It would be incorrect, therefore, to conclude that providing an educated work force would be sufficient to guarantee the growth of jobs requiring such workers. With good jobs in the service sector growing more slowly than the supply of college educated labor, what are the prospects for workers with less schooling who in earlier years would have found employment in the manufacturing sector? Recent growth in employment opportunities in the bottom tier of the service sector suggests that, unless clerical and service workers are displaced by technology, aggregate employment will continue to grow. The available jobs, however, may not provide viable alternatives for workers accustomed to decent wages and due process—union benefits and protections characteristic of much subordinate primary sector employment in manufacturing. Moreover, sex stereotyping of clerical and retail sales occupations operate to deny jobs to displaced male workers even were they to accept the low wages and authority relations typical in such jobs. Can we specify the jobs for which these

[8]See Richard C. Edwards, *Contested Terrain* (New York: Basic Books, 1979); and David Gordon, *The Working Poor* (Washington, D. C.: Council on State Planning, 1980).

[9]Ginzberg and Vojta, op. cit.

[10]Department of Labor, Bureau of Labor Statistics, "Industry Wage Survey: Computers and Data Processing Services," Bulletin 2028, March 1978.

[11]*Employment and Earnings,* November 1981, table B-2.

[12]Richard Freeman (cd.), *The Overeducated American* (New York: Academic Press, Inc., 1976).

young workers should be trained? The future to which they should aspire?

Research Needs

It should be evident from the foregoing analysis that we need detailed, disaggregate data by industry on:

1. the kinds of work suitable for automation, with currently available robots and programmable technologies and with future generations of robots;
2. the number of workers likely to be displaced, and the slowdown in growth or decline in growth of the labor force;
3. the demographic and educational characteristics of the displaced workers;
4. estimates of the average increase in average labor productivity, derived from 1. and 2.;
5. an estimate of the cost saving to be realized as a result of introducing the new technology; and
6. estimates of average labor requirements by occupation, capital requirements by type of plant and equipment, and energy requirements per unit of output at a baseline point prior to the introduction of the new technology, and at discrete intervals in the next 10 to 20 years.

Some of this information already exists in engineering cost studies of technical improvements and in other technical studies done by businesses or consulting firms, in reports of private research firms, and in case studies of individual firms. Access to these studies is sometimes limited and even the published material is not always easy to obtain. A chief difficulty is that it has not been organized into a coherent picture that would enable us to say with confidence what is known and what remains to be learned about the impact of programmable technologies. A survey and synthesis of the existing literature that identifies the gaps in what is known and is followed up with case studies and surveys taken to fill the spaces seems essential. If such a study is undertaken, it should address not only employment issues but changes in the nature of work as well. Changes in work process, management functions, and social relations within firms should all be studied for insights into changes in the quality of working life.[13] In addition, we need to know how widely used in manufacturing the programmable automation technologies will be. For firms that do not directly employ robots and related technologies, we need to know whether they will utilize capital goods produced using such technologies since this will have the effect of reducing capital costs in such industries even without a change in technique (provided, of course, that the price of the capital goods declines).

Information obtained from such case studies can usefully be incorporated into an input-output framework in order to obtain estimates of the size of the labor force, its demographic composition, and its occupational distribution under alternative assumptions about how the technology develops.[14] Final demand might be treated exogenously so that the percentage increase in various detailed input requirements per dollar of aggregate GNP could be calculated. Demand structures that hold constant, respectively, the physical and value composition of output might reasonably provide orders of magnitude for demand effects. Since the assumptions about the new technologies, or "scenarios," are necessarily subject to substantial uncertainty, ranges of plausible technology changes ought to be tested using the input-output framework to assess the sensitivity to changes in the scenarios of the qualitative shifts in demand for energy, labor, and capital inputs.

Input-output analysis refers to changes in physical quantities of required inputs per unit of output. The definitions of capital using and capital saving utilized in this paper depend on the dollar value of investment per unit of capacity. I am familiar with one study that examines that concept empirically for the Canadian economy.[15] That study, which is concerned with unemployment and only touches on the technology issues, uses measures that are aggregated for the economy as a whole. The results are not very useful for the purpose of studying technology, but the methodology is very straightforward. I have put my research assistant to work using this technique to look at particular industries and time periods to determine whether technology has been capital saving or capital using.

[13] For a detailed exposition of the work process issues involved see Eileen Appelbaum, Kenneth Flamm, and Leonard Rapping, "A Proposed State of the Art Survey of the Literature on the Microelectronic Revolution," mimeo, June 1981.

[14] A detailed description of this methodology can be found in Eileen Appelbaum, Robert Costrell, Kenneth Flamm, and Leonard A. Rapping, "The Impact of High Technology on the Structure of Factor Demands and on the Process of Economic Growth," mimeo, March 1981.

[15] Paul Davenport, "Capital-Using Technical Change and Long-Period Unemployment in Canada, 1947-1981," *Journal of Post Keynesian Economics*, forthcoming, September 1982.

ASSESSING THE FUTURE IMPACTS ON EMPLOYMENT OF TECHNOLOGICAL CHANGE: AN INPUT-OUTPUT APPROACH

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July *27, 1982*

The **OTA project proposal on Information Technology, Automation, and the Workplace is an attempt to anticipate now the likely situation with respect to employment of the U.S. working-age population** in one or two decades. This paper describes a methodology for quantifying the size and occupational mix of the employed labor force that will be required as a result of the progressive introduction into the various sectors of the economy of new technologies, in particular production and office automation. It makes frequent reference to a model currently being developed for this purpose at the Institute for Economic Analysis (IEA) with support from the National Science Foundation, called the IEA model.

The input-output (I-O) approach is now used in, or rather as a component of, virtually all the well-known, large-scale models of the U.S. economy like that of the Bureau of Labor Statistics (BLS) Office of Economic Growth and the proprietary forecasting models of DRI, Chase Econometrics, Wharton, and many others. 1-0 is valued in these applications for its ability to disaggregate overall economic activity into sectoral detail and to ensure the consistency of different assumptions made about separate parts of the economy. In this paper I will concentrate on other aspects of I-O that are generally not exploited, and I will try to address the many detailed questions about methodology, assumptions, and data that have been put to me since I agreed to participate in this workshop. I will focus on the issues that can be most readily analyzed at the present time for policy purposes but I will also indicate the research areas into which the I-O framework can and should be extended to integrate issues related, for example, to education and training into the analysis of employment and technological change.

Representing Technology and Technological Change

The technology used in a particular sector can be characterized by the mix and amount of each input required to produce one unit of that sector's output. Inputs include raw materials; various types of processed goods and of services; different categories of machines, tools, and other capital goods; and an assortment of labor skills. A technology is most concretely associated with a single production process, for example use of the open hearth v. the basic oxygen furnace for steelmaking, each requiring a different mix of inputs. Since one technology displaces others only gradually, there are generally several distinct processes in use in a given sector at any particular time and also several stages of production; the sector's "technology" is the weighted average input structure of the various processes in use. The technological structure of an n-sector economy in a given year can be described by three matrices of coefficients: the A matrix (nxn) of intermediate inputs (or interindustry transactions), the B matrix (nxn) of capital stock requirements, and the L matrix (mxn) of labor requirements, assuming m occupational categories. All coefficients are expressed per unit of output.

This description is not of course assumed to be an adequate basis for actual production: it is like the list of ingredients for a recipe which does not include the directions to the cook. Rather, technology is being described in terms of the demands placed by a sector on the rest of the economy.

Technology defined in this way also reflects other inputs not customarily associated with the choice of production process: "overhead" in the form of legal or personnel services or the purchase of an executive jet. The discussion of scenarios below indicates how one proceeds to isolate the phenomena of interest within this broad interpretation of technology.

A change in the input structure of a given sector (where inputs are measured in constant physical or value units) may reflect any number of underlying factors. In a comparison of statistically compiled, historical I-O tables, it will often be necessary to attempt to distinguish the impacts of different factors. On the other hand, one purpose of designing experiments—or scenarios as they are generally called—is to isolate the changes of interest to assess their separate impacts.

Choice of Classification Scheme

The A, B, and L matrices describe the state of the economy at a given time as classified into n producing sectors and m occupations. The number and choice of categories will depend on the purposes of a particular investigation. (In many practical applications, the abilities to collect the required information and to handle large matrices will also constrain the choice.)

Sectors can be described in terms of industries or commodities: * if each industry produces one commodity or service and no two industries produce the same commodity or service, the two schemes are the same. The confounding factors are the presence of:

1. secondary outputs that are marketed; and
2. in-house operations (essentially "captive" production and producer services) that may, or may not, be the primary output of some other sector. These are not reported as outputs.

The commodity scheme **has** the advantage that the corresponding input structures are more readily interpreted in terms of engineering technology although in the presence of secondary products the "overhead" operations may be difficult to allocate to individual commodities. The IEA model uses essentially an industry classification for practical reasons: the labor and capital data and price deflators are much more readily available in that form (for historical reasons). At the level of sectoral detail of the IEA model (the **85** sectors are identified in Annex 1 along with the 54 occupational categories), industry and commodity largely coincide; the divergence between the two necessarily increases with progressive product disaggregation. Practically speaking, any scheme is a compromise between the two,** and it presents no particular conceptual problem to disaggregate some part **of** the economy more than others.

For present purposes, let us consider the case of robots which may be produced for an establishment's own use, for sale, or some combination of the two, In a commodity scheme, robots would constitute a sector which is the sole source of (domestically produced) robots for all other sectors even, say, the automobile sector, although the automobile ***industry*** might produce most of its own robots. In an industry scheme, the input structure of every sector that produces some robots would need to be modified to reflect the production of robots in addition to the creation of a separate robotics industry. The former is easier to implement (and is the approach chosen for this sector in the IEA model even though most other sectors are classified by industry). Both representations will lead to the same conclusions as to the effects of the use of robots on the economy as a whole and as to the total (direct plus indirect) labor requirements of each sector. They will differ in a well-defined way in the computed allocation between direct and indirect requirements of individual sectors.

If the automobile sector produces all of its own robots, the labor used in producing these robots (the vector L) is charged directly to the automobile sector (still L) will be counted as indirect. The vector L itself can easily be computed given either representation and allocated in any desired proportions between what are reported as the direct and indirect labor requirements of the automobile sector. Eventually it may be important to distinguish between the **average input structure of General Motors robots and say, those produced by Unimation for other users. In this case the single producing sector would have to be disaggregated into several, producing different types of robots.**

Data

The principal sources of data for the IEA model have been official government series produced by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce (input-output tables and capital flow tables for **1963, 1967,** and 1972) and by BLS (industry-occupation matrices for 1960, 1970, and 1978 and industry price deflators). The sources of these data are given in Annex **2.*** We have relied also on manual and automated search of the open business and technical literatures, reports of private research organizations, and some interviews and informal surveys.

There is no substitute in terms of scope and comprehensiveness for the official data. At the same time many of their limitations are well known and have been described in various places. For example, a great deal of effort has been expended at our Institute to render the data tables ***compatible*** with respect to assumptions and classifications.

The official I-O and capital flow tables can be considered accounting type data in terms both of their basic sources and the methods used in compiling them. Relatively little use is made of technical sector experts in evaluating the input structures (i. e., table columns); this is one objective of the IEA case studies described below.

There is no concrete concept in the official data of output units for the so-called service sectors; consequently many of the associated price deflators are largely arbitrary. ** This situation makes it hazardous to analyze the changing position of **the non-goods-**

'An industry in this usage is the set of establishments that produce a given principal output: they may in addition produce (the same or different) secondary outputs.

•● The sector including mills producing two slightly different grades of paper could be considered an industry with a secondary product. Alternatively, it could be considered a single commodity.

'Historical data have been assembled because the model will also be used to examine the period from about 1960 to the present: they are not used to extrapolate the structure of the economy in the future from a time series description of the past.

● 'It might be pointed out in a discussion of price deflators that for other reasons the official deflator for computers implies no change in real price over the past two decades. We have instead assumed an average annual *decrease* of 10 percent which more accurately reflects the already steep increase in their use.

producing sectors, which broadly defined already employ about two-thirds of the labor force, based on these tables. In attempting to make some progress in this area, we have concentrated first on the education sector: it is a large employer, it is the source of training and retraining, and it is easier to improve than most of the other service sectors. We have redefined the unit of output and disaggregated public education from health care and nonprofit organizations in the capital flow tables using fragmentary information from government studies and the other types of sources indicated above.

The capital flow tables compiled by BEA would be even more useful if sector experts brought more information to bear on the present methods of allocating a particular capital good among using industries. The official data on capital stock requirements by using industry distinguish only between plant and equipment. A detailed breakdown by type of capital based not only on deduction from flow data, but including direct survey, should be a high priority objective. We have constructed very tentative stock matrices for the IEA model based on the capital flow tables.

The IEA model will make use, through its case studies, of the available business and technical literature and the data and reports of private organizations, which contain a wealth of information but require a great deal of effort to piece together into a coherent picture. An example of this source of information is the "composite forecast" prepared in electronic and hard-copy form by Predicasts, Inc.: an illustrative table describing robots in the U.S. market is shown in Annex 2. Not surprisingly a number of vendors of detailed economic information either use or have expressed active interest in using I-O both as an organizing device and to improve the consistency of a great quantity of numbers taken from diverse sources.

Information for describing, for example, a robot sector, which had little economic significance in the year of the most recent official tables (1972), was pieced together from other sources including the items referenced in the Predicasts forecast mentioned earlier and informal interviews and written surveys by our own staff of knowledgeable individuals willing to cooperate, for example the president and the manager of personnel of a major producer of robots. This type of survey is also the basis of the so-called ex-ante I-O tables compiled by the Battelle Memorial Institute in a more formal and standardized fashion. *

● The Battelle tables are based mainly on surveys of engineers. We have for various reasons not been able to make use of these tables for ongoing Institute work but consider them a valuable source of information-and, more important, a valuable methodology-for use in future work.

Case Studies

Any model that uses an I-O module has at least indirectly to be concerned with the representation of technology and technological changes, but typically this concern is indeed indirect. The historical data are usually accepted as given in the official sources. The coefficients describing the structure of the economy in the future are generally estimated by a formal statistical procedure with little effort at interpreting the technical structure implied by it. In most cases where an I-O module is used to disaggregate the projections which have been made by an aggregate econometric model, technological change is not at the center of attention.

The case studies being carried out at IEA vary in scope and depth but have a common purpose: to ***evaluate and improve*** the corresponding portions of the available historical I-O type data (i.e., A, B, and L matrices) and to ***project*** these data to the future on the basis of alternative assumptions about structural change in the sector under study.

Two of the case studies carried out at IEA on robotics and education have already been mentioned; others include the chemical, iron and steel, automobile, textile, and health care sectors, and telecommunications, office equipment, and computers are in progress. The robotics study, for example, includes a compilation of current, capital, and labor input vectors for the U.S. robotics producing sector circa **1990. In** addition, it projects the level of robot purchases for 45 likely using sectors. In each using sector, seven occupations in which workers are likely to be displaced by robots and two which will be required in greater number because of robots, are identified. The percentage change in labor input requirements (for each occupation in each using sector) is projected under alternative assumptions. The quantitative output of the case study is the direct input to the computer programs.

The Dynamic Model

The basic objective of an I-O analysis of the impacts of technological change on employment is, in operational terms, to quantify the levels of detailed labor inputs which will be required in a given year to satisfy any given level and composition of final demand, making alternative assumptions about production technologies (i.e., using alternative A matrices). In an open static model, the level and composition of final demand, which includes private and public consumption and investment and net exports, are exogenous; they are implicitly assumed to be relatively independent of the technologies in use. Almost all empirical I-O

analyses have been carried out within an open static framework.

In a fully closed dynamic model, at the other extreme, the different components of final demand are explained ***endogenously.*** For example, trade flows in the IEA World I-O Model are parameterized by means of region- and commodity-specific import coefficients and export shares, and the levels of imports and exports are thus computed endogenously. (In the open model one can—at least in principle—using alternative assumptions concerning the exogenously determined exports and imports, ***approximate*** changes in the structure of foreign trade that are taken care of automatically (i.e., endogenously) in the closed model.)

The present version of the IEA model represents a significant advance in the endogenous determination of investment. * In experiments carried out with this model, investment will be governed by a B matrix associated (in terms of technological considerations) with each A matrix. Exogenous final demand will ***exclude*** private fixed capital formation which will instead be computed endogenously to satisfy in level and composition the production of a particular final bill of goods. This means of course that the labor required to produce these investment goods will also be appropriately computed,

Scenarios

A scenario is an experiment carried out within the framework of the model to address a specific question. The starting point is a description of the I-O structure of the economy (i. e., A, B, and L matrices) for each year in the time horizon under examination, and each scenario consists of specific alternative assumptions about how that structure (i. e., the individual coefficients in the A, B, and L matrices) might evolve. The size of the labor force and its composition by occupation as implied by each scenario are then computed (along with many other variables) and can be compared across scenarios. It is standard practice to define a baseline scenario for purposes of comparison. In the IEA model the baseline scenario assumes that the present I-O structure of the economy remains unchanged in the future.**

Scenarios may differ in their assumptions about virtually any aspect of the economic structure. I will briefly discuss some possible scenarios about the rate of adoption of automation, the identification of the occupations affected and quantification of the impact on individual labor coefficients, and the level and composition of final demand, These are the types of scenarios that can be most readily computed at the present time. As the model is progressively "closed" with respect to other components of final demand, a scenario approach will also be used to represent alternative assumptions about the constraints under which the economy operates.

In order to represent the use of programmable automation, it is first necessary to distinguish in physical terms the types of automation equipment in question, by what combination of existing and new sectors it will be produced, and the input structure for production. Then, depending on the case, it is necessary to identify the sectors and / or the operations in which this equipment may be used and the likely level of use. The occupations of workers that may use both the automated equipment and that which it complements or supersedes must be specified, along with other affected current and capital inputs of the using sector, on a per unit of output basis. All the assumptions must of course be quantified. A standard set of assumptions for **1990** is produced by the associated case study and "spliced" into the A, B, and L matrices for that year and for prior years as required: the actual splicing consists of course of replacing equipment and the corresponding input flows, including labor inputs, per unit of output of a particular sector by new equipment (e.g., robots) and input flows, including labor, required (also per unit of output) by the new technology. (Note that the incremental output—and labor—required in ***prior*** years to **produce the capital in place in May 1990 will automatically be computed.)**

The "standard" assumptions referred to in the preceding paragraph reflect the combination of what we consider to be the ***moderate*** projections of experts dealing with different aspects of, say, robotics. Alternative scenarios incorporate more extreme views, either hypothetical or actually expressed by other analysts. (In later stages of our research, the portions of the case studies dealing with the future will rely increasingly on ***technical*** factfinding; this work will make possible the elaboration of more detailed, technical scenarios.)

Sample robotics scenarios for which preliminary computations have been made include:

- What will be the level and occupational composition of employment in 1990 implied by the standard assumptions of the robotics case study compared to the baseline scenario (assuming in both cases the same projected **1990** final demand bill of goods and the same state of the economy in 1980)?

● A model in which investment is endogenous can be considered a dynamic model. Many models have been called dynamic; in the dynamic I-O model, capital flows and stocks are disaggregated by producing and by using sectors, and the framework requires not onl, intersectoral but also intertemporal consistency in the production and disposition of the highly disaggregate capital stock.

•● "Present" here means the most recent year for which official accounting data are available; I-O and capital flow tables for 1977 should be available in the near future,

- What if one additional mechanic is required for every three robots instead of every six robots in each using sector?
- What if each using sector acquires twice as many robots as under the standard assumptions?

Scenarios will also be developed for office automation involving changes in the use of telecommunications equipment, computers, and office equipment by clerical and certain categories of managerial and professional employees in all sectors. Production automation, involving essentially computers and sensors (as well as robots), includes process control, computer-aided design and manufacturing, inventory control, and scheduling. While the latter case study is more complicated, the investigation will follow the same approach. Scenarios will specify values for the amount of use and the impacts on individual I-O coefficients of different forms of automation, singly and in combination.

The following type of scenario is included to give a concrete idea of the range of questions that can be addressed in the near future with the present model and expanded effort on the case studies:

- The different case studies deal with the introduction of specific types of automation equipment into specific operations. Assume that all aspects (that have been identified) of production and office automation proceed at a "moderate" pace over the next 10 or 20 years. How will the size of the employed labor force evolve? Which occupations will experience the slowest growth (or greatest decline)? What will be the demand for computer programmers?

Policy and Research Issues

For policy purposes it is necessary to have a model that can produce results quickly and inexpensively. This can be achieved if:

1. there is a methodology for preparing at least certain types of scenarios quickly by human analysts, and
2. the computer software is designed (among other considerations) to process an entire scenario as a single input.

The section on scenarios describes the types of scenarios for which these two considerations can be met most readily. The software design issues are well understood.

The case study approach has been developed to provide the required format for scenarios, and improving the scope and depth of the case studies should be a high priority. In fact, "micro" studies now sponsored by the policy community for more general factfinding purposes could be guided to include a section structuring the information content into a format that would permit its being used directly by a model such as the one described.

In subsequent work on technological change, the IEA model can and should be "closed" with respect to trade, accomplished by integrating it into the World Model. This will make it possible to analyze a considerably expanded range of policy scenarios where U.S. production is directly linked to its trading partners' economic activities. In the open system, these impacts are instead approximated by ***hypothesizing*** changes in U.S. imports and exports.

From a research point of view, there are many avenues of work that would improve the accuracy of the projections of the basic model (without even touching for present purposes on the important area of computational research).

Additional basic research is required to make further conceptual advances toward a fully dynamic I-O model in addition to the critical need for better data on capital flows and especially capital stocks, on a disaggregated basis.

The other important area for further work is the incorporation of a demographic model into the dynamic I-O model. This would provide the basis for improving and rendering consistent the projected demand for education and health care as well as other components of household consumption.

THE EFFECT OF TECHNICAL CHANGE ON LABOR

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July 27, 1982

Summary

Technical change, which makes possible the production of more output from a given amount of resources, is a major contributor to increases in society's wellbeing. The very process of change may, however, impose hardships on those who use old and no longer efficient methods or produce products that are no longer wanted. The net effect of technical change on labor is hard to predict. Workers, as consumers, gain from increases in productivity; they are able to buy things at lower prices. If they cannot adapt to new production methods (and lose their jobs as a result), they can end up as net losers,

Not only is the effect of technical change on labor hard to predict, but technical change itself is hard to define and measure. It cannot be measured simply as the installation of new (and different) equipment. Nor can it be measured solely as the growth of productivity. All three—technical change, new equipment, and productivity growth—are related. A goal of this paper is to clarify the relationship.

It is important, at the start, to distinguish technical change resulting in the appearance of new products from a change in production processes. To some degree, this distinction is artificial; programmable automation equipment is a new product of industries producing capital goods, but its use represents a new process in other industries. Both new products and new processes can affect labor. The development of a new product —passenger aircraft—and new processes—assembly-line methods of production of automobiles—led to increases in employment in those and a host of related industries—home construction, leisure products, etc. At the same time, workers in other industries—horse-breeding, saddle-making, the rail passenger industry-were being squeezed out into other jobs. Now, changes in production technology, here and abroad, are leading to a reduction in employment in auto production and autoworkers are having to adjust.

We analyzed the effects of technical change on workers in two steps. The first step is to estimate the effect of technical change on an industry's employment. We concentrate on the effect of new process innovations since these are likely to have more concentrated impacts on employment. The next step is to estimate the effect on individual workers: How many workers are displaced during the adjustment process? How long does it take them to find new employment? How much does displacement affect their earnings?

The Industry Cost Model

To determine industry effects, we use an econometric model of cost in which cost is assumed to depend on the prices of factor inputs, the level of industry output, and the level of technology. This is the standard analytic approach in economic studies of technical change. The rate of growth of total cost is composed of the weighted average of the rates of growth of input prices, a weighted rate of growth of industry output, and the rate of cost reduction due to technical change. Technical change is therefore only one determinant affecting industry cost; input price changes, for example, may be more important.

We included five factor inputs—production labor, nonproduction labor, capital, energy, and materials in the cost function and imposed no restrictions on how they can substitute for each other. We assumed cost minimization and estimated how technical change has affected the steel, auto, and aluminum industries. The model was estimated at the four-digit Standard Industrial Classification (SIC) category, a finer level of disaggregation than that used in most industry studies.

One of the advantages of using this kind of model is that with relatively few variables, much can be learned about factor substitution, input adjustment, and the effects of technical change. Data on input quantities and prices, industry cost and real output, and the level of technology are almost all that is needed. Data needed to measure capital and technology is often difficuIt to find, but the model clearly specifies what is needed for estimation.

Equations in the econometric system illustrate important relationships. For example, equations that express the dependence of each input's share in total costs on all input prices, output and technology maybe used to describe how input-output coefficients, which are measured similarly to input shares, move over time. More important, the equation also describes why they move. **It explains changes** in input-output coefficients in terms of: 1) adoption of new techniques, 2) changes in input prices, and 3) changes in scale.

For labor, the equation describes how changes in labor's share (i.e., the ratio of payroll to total cost) depend on changes in the wage, other input prices, output, and the level of technology. The effect of any variable on labor's share is obtained from the regression estimates. For example, the effects of technical change, holding prices and output constant, is described as labor saving, using, or neutral if the parameter on technology is negative, positive, or zero. Labor-saving technical change means that as technology increases, the share of payroll in total costs goes down. The estimated equation can then be used to derive the effect of technical change on the demand for the ***quantity*** of labor.

Another equation in the system maybe used to explain the relationship between the rates of technical change and productivity growth. Productivity growth is measured in terms of total factor productivity rather than labor productivity, which is only a partial measure of input use.

The rate of productivity growth has two components. The first is the rate of technical change. The second depends on the relationship between changes in industry cost and output changes. Most researchers assume that, in longrun equilibrium, industry cost and output change proportionately. This assumption, called "constant returns to scale, " is often imposed on the equations. If this assumption is correct, then this second component of productivity growth becomes equal to zero, making the rates of productivity growth and technical change equivalent. Thus, low rates of technical change would imply low rates of productivity growth.

We feel, however, that constant returns to scale is too strong an assumption. Certain factor inputs, like capital and nonproduction labor, maybe "fixed;" they cannot be adjusted quickly without incurring large cost. Because of these fixed inputs, costs do not change as much as output. This means that studies that simply impose constant returns to scale, thereby disregarding the second component of productivity growth, will overstate the effects of technical change.

The Measurement of Industry Technology

Thus far, we have illustrated that technical change is only one determinant of industry cost changes and one component of productivity growth. We have not yet related technical change to the introduction of new technologies.

To do this in an econometric model required measurement of the level of industry technology. The standard approach is to represent the level by a time trend. **This is satisfactory if changes in technology unfold regularly and gradually. It is unsatisfactory if new processes are introduced rapidly, that is, within a relatively short period of time. This distinction is important** since sudden or unexpected shifts in production processes and labor demand may make adjustment difficult for the industry's work force.

To be as precise as possible, we therefore constructed direct measures of steel and auto technology. (A measure for aluminum could not be constructed.) For steel, the measure was based on the use of the basic oxygen furnace, which is important in the steelmaking process. Technological innovation in the auto industry since World War II has proceeded under the term "Detroit" automation. The term refers generally to the substitution of machines for workers in actual production processes, such as welding. To quantify the concept of automation, we measure the stock of transfer machines, the basic unit of Detroit automation.

Empirical Results of the Cost Model

In our empirical work on steel and autos, we compared the precise "direct" measure with the simpler time trend. The findings were about the same; the use of the direct measure added little precision to the estimates of the effect of technical change beyond what we estimated using the time trend. Regardless of how technology was measured in steel and autos, estimates of the rate of technical change in the industry were similar. We found the average rate of technical change to be virtually O percent in steel. It was just under 1 percent in aluminum, where little new process innovation has been observed, and 1.50 and 2 percent in autos (the higher figure was for the time trend version). These findings illustrate the tenuous connection between new process innovation and technical change.

The effects on input demand are similar across industries when the time trend is used to represent technology. We found that technical change was labor saving and capital using. This meant that, holding input prices and output constant, labor's share was decreasing over time while capital's share was increasing by about the same amount. In autos, in the 1970's, labor demand decreased by about 4 to 5 percent a year.

When direct measure was used, the results for steel were about the same as when the time trend was used. For autos, there were some differences from the time trend regression. There were smaller negative effects on labor and smaller positive effects on capital. One tentative interpretation of this is that advances in technology meant that newer capital was more productive than the capital it replaced and that it used only slightly less labor.

In summary, we found that the effects on employment of introducing new technologies, whether measured directly or by a time trend, were indeed negative but occurred gradually. We did not find evidence of abrupt changes in the demand for labor. Some of the empirical estimates differed according to how technology was measured, but the implications for employment adjustment were essentially similar. Given these similarities, the time and expense of creating direct measures seem unnecessary. The exploration of other issues may prove more fruitful in determining how new technologies affect employment.

As an example, our findings point to an interesting implication of the generally labor-saving and capital-using effects of technical change. When the price of labor increases relative to capital, little short-term substitution of capital for labor takes place. Over the long term, however, the use of advanced technologies allows capital to be less labor intensive and so the quantity of labor decreases relative to the quantity of capital. This possible "induced innovation" has been difficult to identify empirically. Generalizations of our model may help quantify the link between new technologies and their determinants.

The Effect of Employment Reductions on Workers

We have taken our analysis further than simply examining the effects of technical change on aggregate employment. We have also examined:

- the extent to which employment reductions can be accommodated through attrition rather than displacement, and
- the earnings losses of displaced workers.

Displacement Findings

Our results are that attrition varies widely across industries, from about 5 percent per year in high-wage industries (steel) to about **65 percent** in low-wage industries. If high-wage, low-turnover industries, such as steel and autos, had to reduce employment by 5 percent in a given year, about two-thirds of the reduction could be accommodated by attrition under average conditions. If employment had been increasing prior to the reduction, attrition would be higher, that is, more than two-thirds would be attrition. If employment had been falling, attrition would be a lower proportion. This is because attrition is primarily determined by the tenure structure of the industry. Attrition, which is extremely high among recently hired workers, falls dramatically after a year or two, and is extremely low thereafter until workers near retirement age. Recent hiring and layoff patterns cause large swings in the proportion of the work force that is most likely to leave voluntarily, and this, in turn, causes swings in the attrition rate by as much as 2 percent.

Aside from their effect on the tenure distribution, general business conditions (the business cycle) have little effe6t on attrition. Although other studies show that the quit rate is sensitive to changes in business conditions (and quits are the major element of attrition), those studies generally ignore the changes in the tenure distribution over the business cycle (use imperfect measures of tenure structure). Instead, they rely on aggregate turnover statistics that show a fall in quits during recession simply because workers who would otherwise quit are laid off.

A 5 percent employment decline cannot be fully offset by a 5 percent attrition rate. There will be some displacements because the employment change across firms is not uniform. Even while total employment in the industry is declining some firms will be expanding. Attrition in the firms that are expanding must be replaced by hiring and obviously cannot count against the net decline. The dispersion of firms around the mean employment change is substantial, so that even where employment in the industry is constant, about 1 percent of the employment industry's labor force will be undergoing displacement.

The existence of a more-or-less constant background level of displacement is important. Displacements are most costly when they are entirely unexpected. If workers anticipate a nonzero probability of displacement, they can prepare for that eventuality and reduce its consequences. This appears to be the case in some high-wage industries such as aerospace, which have major boom and bust cycles as a result of military and civilian aviation procurement policies.

Plant closings are a major source of displacements because attrition can do little to offset employment declines when plants close. Closings are particularly likely when a firm experiences a sharp decline in demand: below a certain level of production, it is simply uneconomic to stay in business.

Earnings Loss Findings

Earnings losses due to displacement are highly correlated with attrition rates—high losses go with low attrition. This makes good economic sense; if few workers are leaving voluntarily, this is strong evidence that there are few good alternative jobs, and a worker who is forced to leave will have large losses. Displaced workers experience a transitional period of earnings losses due to lengthy unemployment (a good part of

which may be simply waiting until all hope of recall vanishes*).

When workers begin to search for work, they often will try out several jobs until they find suitable employment. Workers' earnings then begin to rebound but usually, in cases where initial losses are high, they never fully catch up with what they would have earned had they not been displaced. The "permanent" loss is generally between 7 and 15 percent of annual earnings and amounts to about 50 percent of the total earnings loss. (The total loss in industries such as steel and autos is generally equal to about 2 year's earnings.) The transitional loss is about equal to the permanent loss, but it lasts only a year or two. The temporary loss, however, is more likely to be offset by unemployment insurance, SUB, and severance pay.

In analyzing earnings losses, we measured how they vary with respect to age, tenure, labor market characteristics, and the size of the employment decline. Again, tenure was a key determinant of the size of the loss. New hires and workers close to retirement experience small losses, while other workers tend to have large losses. The largest losses occur among workers with about 5 years experience. This is because they have many years over which to accumulate the permanent part of the loss, and because they may be in a position to assume more responsible positions but do not yet have the experience needed to convince another employer that they are ready for such a job.

Labor market characteristics are also important. Loss in the transitional period can be doubled if displacement occurs when area unemployment is high (one standard deviation over average–about 1.3 percentage points). Losses are substantially larger if the displacement has occurred in a small labor market and marginally greater if a large number of similar workers are searching for work. Workers who have been displaced because of a plant shutdown do not have much larger losses than similar workers displaced under other circumstances. A shutdown will, however, displace higher tenure workers who have larger than average losses.

Methodology

This section discusses, in general terms, the methodology used to obtain the above results. The details are discussed in the reports referenced at the end of this paper. The basic estimating equations used to examine attrition and earnings loss are quite simple. Attrition is assumed to be a function of worker characteristics-age, race, sex, tenure, earnings level, and the rate of change of earnings; plant characteristics—employment level (size), employment trends, whether part of a multiplant firm, average wage rate, and trend of wages; and labor market conditions—stage of the business cycle (current unemployment rate divided by the rate at the previous trough), size of the labor market, recent growth rate, average wage rate, and measures of industrial diversity.

Earnings are estimated as a function of many of the same variables used to measure attrition. Prior earnings, however, is the key determinant, since it captures the way in which a host of determinants, which remain more or less constant over time (such as education, health, and marital status) affect a worker's earnings potential. The earnings equations are designed to compare the earnings of displaced workers to those of similar workers who are not displaced but are initially employed in the same industry. Econometric tests are applied to ensure that the equation matches the earnings of the two groups exactly.

The procedure for estimating how employment changes are distributed across firms in an industry is more complex. We assume that units use a strict LIFO (last-in-first-out) displacement rule. Given this assumption, the seniority distribution of displaced workers is also the cumulative distribution of employment changes across all the individual units. The actual seniority distribution is calculated by observing the tenure of displaced workers and relating tenure to seniority. This procedure is used to examine displacement under a range of circumstances and then econometric techniques are applied to generalize the results.

Data

All three estimating procedures are carried out with the same data set—Social Security's Longitudinal Employer-Employee Data (LEED). These data contain the age, race, and sex of a continuing 1 percent sample of the work force, each individual worker's quarterly earnings from each employer, and the employer's industry, location, and firm size. The data cover the years 1957 through 1975. Job changes are noted by a change in the employer who files a quarterly earnings report for the worker.

A key problem is that there is no explicit indicator of the reason for separation in the data. Thus, we must infer whether a worker who changed jobs was displaced or left voluntarily (attrition). To measure attrition, we isolated a sample of workers who changed jobs when employment in their plant (or sometimes area) was increasing or stable. We assume that under such circumstances, no displacements were taking place. The earnings loss due to displacement is esti-

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● **A large fraction of workers laid off eventually are recalled. In fact, temporary unemployment is the largest component in the cost of an employment reduction, but the cost is low per capita, and industrial workers generally anticipate several episodes of substantial temporary unemployment.**

mated using a simultaneous equation approach that compares the earnings loss of leavers in firms where employment is growing or stable to the loss of leavers in firms where employment is falling. It is thus possible to net out the effect of attrition from the effect of displacement. In practice, it turns out that holding constant the other factors mentioned earlier, earnings reductions are relatively insensitive to whether displacement or attrition was the reason for the job change; both the displaced and voluntary leavers have similar earnings reductions.

The LEED file is not the only data base suitable for estimating earnings losses. We have also used data from State employment security agencies (UI offices). These data include wage records that closely resemble those in the LEED file, but they also include information on the worker's receipt of unemployment compensation, last day worked, occupation (in some cases), and the reason for separation (if the worker claims UI). Thus, these data contain a richer set of variables. A major value of these data is examining the extent to which transitional losses are offset by the receipt of UI. For example, we recently used data of the type to study TAA (Trade Adjustment Assistance) recipients in Pennsylvania and concluded that more than 50 percent of the transitional loss in earnings is replaced by UI benefits.

Summary and Conclusion

Our research on the effects of technical change on employment has been aimed at measuring technical change and its effects on labor in the steel, auto, and related industries. State-of-the-art econometric models were used to determine the effect of technical change on employment and to measure how displaced workers adjust.

Our basic conclusion about the effect of technical change on employment is that, while technical change was labor saving, it occurred at a steady and relatively slow pace. It appears that new technologies were adopted principally to avoid increases in labor costs.

Detailed description and measurement of the installation of new technologies, such as transfer machines in autos and the basic oxygen furnace in steel, seems no better than the time trend in measuring how technical change affects employment. This reinforces our conclusion that technical change in established industries (process innovation) is slow and steady.

We also linked technical change in one industry to its effect through factor prices on the other industries. This allows comprehensive measurement of the net employment effect of innovation. Although technical change in steel reduced employment in the steel industry, the change in steel *increased* employment in autos by reducing the price of a key input.

Our models have been carefully checked and tested for sensitivity to key assumptions. They represent a good way to measure the effect of technical change; the same methodology can successfully be used in future research. In particular, we believe tracing the effects of individual technologies is not worth the high cost. The effects of changes in consumer preferences, factor prices, and foreign competition on labor demand are likely to be far more important and can change far more swiftly than production technology, as we learned in the 1973 oil embargo. One fruitful extension of this approach would be to investigate the determinants of technical change itself, such as the extent changes in factor prices induce factor-saving technical change.

We have also analyzed how employment reductions affect workers employed in a given industry. Employment reductions are costly to labor primarily when workers are displaced from established jobs, but reductions that do not result in displacing workers are almost costless. The work, therefore, addressed how employment reductions are distributed across plants and how much of the reductions can be accommodated by attrition. The cost to displaced workers was also assessed.

Our basic conclusion is that employment reductions can be handled largely through attrition. The main threat of dislocation is from plant closings. Although major plant closings occur rarely, we calculated that they are responsible for half the displacements in the steel industry. Our work on earning losses showed that when potential losses are large, the attrition rate is low. Thus, in industries where few workers leave voluntarily, such as steel and autos, major employment reductions are likely to be very costly and can involve substantial displacement. On the other hand, employment reduction in high turnover industries, such as textiles and apparel, have minimal adverse effects on workers.

In terms of future research, further work on attrition is called for. We found that attrition is largely a function of the tenure structure in an industry, but other research suggests that cyclical conditions are a key determinant of attrition. Although these two explanations are not necessarily contradictory (the tenure structure changes as a result of cyclical hiring and layoffs), it is important to determine whether bad business conditions reduce attrition holding tenure structure constant, If, contrary to our evidence, attrition falls in a recession because general business conditions worsen, we will have overestimated an industry's ability to adjust to employment reduction without displacing many workers.

A **second objective of future research is to explain why workers,** in industries such as steel and autos, suffer such large losses and what government can do about it. There is a widespread feeling that these losses are an indication of a failure in the functioning of the labor market. In the extreme form, it is assumed that displaced workers "fall off the end of the earth" and never adjust. Competing explanations are that the earning reductions represent normal job search costs plus loss of high wages attributable to unionization or specific human capital.

If market failure is responsible, an effort should be made to determine its cause. If specific failures can be isolated, there is a reasonable chance that government action can help eliminate them at low cost. If loss of union protection or human capital are involved, policymakers should recognize the constraints this implies.

Our evidence is that where losses are large, displaced workers adapt to new jobs but never regain the earnings level they would have attained had they not lost their jobs. The adjustment is painful; often 5O percent of the loss occurs in the first 2 years. The "permanent" loss is about 7 to 15 percent, about that estimated for union/nonunion wage differentials. This evidence is consistent with the hypothesis that losses are due to loss of union protection or specific human capital. If this view is correct, a policy that will fully eliminate the loss must raise the income of an experienced worker about **$2,500** a year or about $40,000 in present value terms. Thus, any government actions to eliminate losses such as training or enhancing unemployment insurance will be expensive.

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PROGRAMMABLE AUTOMATION: ITS EFFECT ON THE SCIENTIFIC= ENGINEERING LABOR MARKET

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July **27, 1982**

Adjusting to Technological Advancement

Introduction: An Analytical Framework

Technological change and innovation play a predominant role in productivity and general economic growth. They also create shifts and movements in the supply and demand for labor. In particular, they are presumed to require the labor force to adjust or respond to demands for alternative knowledge and skills. Generally, the theoretical construct for determining the supply and demand for labor (or the impact of technological change on shifts in supply and demand of labor) is the production function **(6).** This function (whether Cobb-Douglas or C. E. S.) expresses how the final product (output) is a function of inputs (for simplicity, capital, and labor) and how the inputs are related. For example, the marginal product produced by capital or labor is derived by differentiating the production function by either input. As either increases its marginal product (ceteris paribus), the demand for its services increases over the other.

The relationship of inputs to outputs, and inputs to inputs are influenced heavily, however, by the existing technology. Technological change, in turn, alters these relationships in several important ways—including changes in: 1) the efficiency of technology, 2) economies of scale, 3) capital intensity, and 4) elasticity of substitution. Moreover, technology change either is neutral or nonneutral. Neutral changes in technology affect technological efficiency and technologically determined economies of scale. These alter the relationship of inputs to outputs. Nonneutral changes, on the other hand, affect the intensity of technology between inputs. An increase in capital intensity is labor saving when capital is a more rapidly growing factor of production than labor. "Many economists have the feeling that technological change has been quite labor-saving, but they generally acknowledge that the evidence is indirect and too weak to permit a clear-cut judgment" (12).

A further dimension to the production function analysis is found in what has been termed embodied and disembodied technological change (17). The former generally refers to actual physical changes in the capital equipment being operated and assumes that it becomes more productive. The latter concept is usually characterized by managerial or organizational changes which cause the interaction of capital and labor to be more productive. Generally speaking the analysis of programmable automation can be treated as embodied technological change. In summary, the production function framework suggests that embodied technological change raises the marginal productivity of capital relative to labor. It does this through increasing the intensity of technology and the elasticity of substitution. Thus, everything else constant, the demand for labor shifts. For the most part, such shifts cause the substitution of capital for labor, and/or one type of labor for another.

Postschool Education, On-the-Job Training, and Turnover

Although the production function offers a useful framework for conceptualizing the impacts of technological change on the demand for labor, our present interests require us to go beyond this framework. We seek a framework that explains the type and level of human capital adjustments made by labor as the demand curve for specific skills is shifted by embodied technological advances. The widely applied theory of investment in human capital lends itself well to economic choice modeling and to an analysis of earnings. The theory takes a labor supply perspective. Workers make decisions about their labor force behavior in response to the derived demand for alternative skills or knowledge. Thus, demand conditions are given and the supply of workers responds. Human capital theory maintains that worker response is in the form of income maximization over the working life. Since derived demand is dynamic, labor supply is dynamic. What may have been a good decision previously may become a poor one later if the worker does not adjust to changes in demand. According to human capital theory the incentive to adjust (or not adjust) primarily is pecuniary. In effect, the theory holds that a person makes an investment of resources in upgrading his or her productivity. Couched in the marginal productivity thesis, workers get paid the value of their productivity. Consequently, increases in productivity are assumed to lead to increases in income. Since the investment of resources (primarily foregone earnings) is costly, individuals weigh the present value of the increased flow of future income against the present value of the cost of the investment. Income maximizing individuals will make investments in those alternatives with the highest rates of return.

The theory is an exact interpretation of very inexact reasoning on the part of individuals. The theory has received much criticism, especially for its simplicity of the "economic man" concept (ignoring the nonpecuniary incentives of selecting occupations or furthering education—at least in empirical work). However, the concept of maximizing utility readily fits into the investment framework. It is the measurement of nonpecuniary returns that eludes the researcher. The theoretical framework is a useful one for the present analysis because it explains behavior as a function of price (cost and earnings) and it encompasses formal educational training (both early and later in the career), on-the-job training (OJT),* quit behavior, and occupational changes.

Although not fully developed at this point (nor widely embraced by economists) "implicit contract" theory promises to improve our understanding of labor market adjustments (1,2,3,8,9,11). The implicit contract framework addresses better the employer's part in the human capital investment decisionmaking. In particular, it addresses the decision of the firm to provide OJT and to influence turnover. Succinctly, because workers are more risk averse vis a vis employers, employers are willing to provide more stable employment and less risky OJT investments in exchange for lower wages. Without developing the theory more fully here, let me emphasize that an examination of labor market adjustments to technological change should consider employer as well as worker decisionmaking.

What kind of alternative choices do workers and employers make when rapid advancements in technical knowledge and skills lead to obsolescence? For scientists and engineers (S/Es), these choices include reading professional and trade literature, participating in workshops and conferences, returning to school (part- or full-time) (10), investing in formal and/or informal

*** Editor's note: OJT is more broadly defined in this paper than in ch. 3 of the text where it refers only to informal skill acquisition.**

OJT, and changing jobs. Changing jobs includes both changing employers and/or changing occupations (either within or out of S/E occupations). Employers, likewise, have alternatives for retooling their work forces experiencing obsolescence. Primarily, these options include providing informal and formal OJT, reassignment of job tasks, and laying off workers with obsolete human capital (and, in turn, recruiting new talent).

Investment decisions made to replace obsolete human capital probably are influenced most strongly by **age,** which affects investment behavior in several ways. In its simplest form the relationship between age and investments is considered dependent on the time horizon for receiving returns. Older persons simply invest less because they have fewer years to receive investment returns. For the same reason, employers restrict opportunities for older workers. Secondly, investments will decrease at an increasing rate with age if older workers become less efficient in producing human capital. Ben-Porath addresses this possibility in testing his "neutrality hypothesis. " The neutrality hypothesis assumes that the efficiency of human capital production and market production remains constant throughout the career. Any shift in efficiency towards the production of goods and services in the product market reduces the likelihood of producing further human capital.

A third dimension to the relationship between age and investment probabilities is deterioration. Like physical capital, human capital can deteriorate over time as a result of obsolescence and / or depreciation. According to Rosen **(16),** obsolescence indicates that more vintaged knowledge has become outdated by more recent knowledge. This can be caused by advancements in the sciences, production innovations which render existing skills useless, and the "increasing abilities of successive generations. " Depreciation, on the other hand, indicates a loss of ability by individuals to apply their existing knowledge and skills. This presumably goes hand in hand with age as physical and mental capacities diminish.

Although most modeling treats obsolescence and depreciation as one (usually a depreciation factor), the distinction between the two is especially important to the study of S/Es where technological and scientific advances make relatively specialized skills obsolete more quickly. To keep abreast of these advancements and to at least protect themselves in the labor market, scientists make further investments in their human capital stock. In contrast, depreciation reduces the capacity to apply one's stock of human capital to production, which reduces the rates of return to further investments, and, thus reduces investments.

Other important determinants of investment behavior for S/Es include education level, labor market conditions, years of experience, tenure with present employer, sex, and government contracting. When the determinants of investment behavior cause disincentives to retooling obsolete skills, S/Es are more likely to change employers, occupations, industries, and incur spells of involuntary unemployment.

Adjustments by Occupation and Industry

Below are several tables providing frequencies on the incidence of various adjustments. The figures presented in these tables are based on the National Science Foundation's (NSF) Longitudinal Survey of Scientists and Engineers (NLSSE). There is no attempt here to tie these adjustments to technological change. (See ref. 7 for a more in-depth description and analysis of these adjustments.)

Table C-1 provides observations on the frequency of investments in postschool education and OJT by S/Es. Occupational classifications are based on the respondent's self-concept.

Roughly **6** percent of the scientists and **4** percent of the engineers made formal educational investments in the same field, whereas about 10 percent of both samples invested in other fields. Considerably more investments were made in OJT and in course work provided at the employer's training school: 19 percent of the scientists and 18 percent of the engineers invested in OJT and 16 percent of the scientists and **20** percent of the engineers took courses at the employer's training facility.

Table C-2 provides figures on the percent of S/Es undertaking OJT by selected manufacturing industry. The incidence of formal OJT ranges from a low of 15 percent of the S/E work force in the fabricated metals industry to a high of 36 percent in the electronic computer industry. The incidence of reported informal OJT ranges from a low of approximately 16 percent in the aircraft industry to a high of **36** percent in the electronics computer industry.

Table C-3 provides observations on the frequencies of voluntary and involuntary turnover by S/Es over the **1969-72** period. Quit frequencies indicate that agricultural scientists were the least likely to quit during this period (7 percent) and that physicists had the highest quit percentage (15 percent). Among engineers, aeronautical / astronautical engineers had the highest frequency (5 percent) and agricultural scientists had the lowest frequency **(0.4** percent). Among engineers, aeronautical / astronautical engineers had the highest permanent layoff incidence (8 percent) and mining/

Table C-1 .–Frequencies of Postschool Education and On-the-Job Training by Scientific and Engineering Occupation, 1972-74

Occupation	Postschool education: Same field	Postschool education: Other field	On-the-job training: Formal	On-the-job training: Informal
Scientists:				
Agricultural	0.035	0.055	0,242	0.315
Biological	0.048	0.123	0.055	0.141
Chemist	0.064	0.070	0.130	0.158
Earth/marine	0.052	0.054	0.212	0.196
Physicist	0.088	0.075	0.076	0.087
Engineers:				
Aeronautical/astronautical	0.052	0.133	0.217	0.156
Agricultural	0.055	0.055	0.273	0.164
Chemical	0.049	0.090	0.184	0.210
Civil/architectural	0.043	0.084	0.153	0.186
Electrical/electronic	0.063	0.106	0.240	0.176
Industrial	0.012	0.129	0.226	0.219
Mechanical	0.032	0.095	0.189	0.163
Metallurgical/materials	0.041	0.090	0.178	0.134
Mining/petroleum	0.023	0.062	0.229	0.209

Table C-2.—Formal and Informal On-the-Job Training Frequencies by Selected Major industries, 1972.73 (working full-time year round in same job)

Industry	Percent of formal OJT	Percent of informal OJT
Aircraft[a]	25.4%	15.50/0
Chemicals[b]	22.2	23.6
Electrical machinery	30.1	19.7
Electronic apparatus	28.0	17.6
Electronic computerese	46.3	35.5
Fabricated metals[f]	15.3	17.3
Machinery (except electrical)[g]	18.6	17.4
Motor vehicles[h]	31.2	21.8
Ordinance[i]	31.2	19.3

[a]Aircraft, aircraft engines, and parts.
[b]Chemicals and allied products.
[c]Electrical machinery, equipment and supplies for the generation, storage, transformation, transmission, and utilization of electrical energy.
[d]Electronic apparatus, radio, television, and communication equipment and parts.
[e]Electronic computers, accounting, calculating and office machinery and equipment.
fabricated metal products (except ordnance, machinery and transportation equipment.
[g]Machinery (except electrical) including engines and turbines, farming arcónstruction machinery, mining, metalworking, and other manufacturing and service industry machines.
hMotor vehicles and motor vehicle equipment including trucks, buses, automobiles, railroad engines and cars.
[i]Ordnance, including manufacture of arms, ammunition, tanks, and complete guided missiles, space vehicles and equipment.

Table C-3.—Frequencies by Voluntary and involuntary Mobility by Scientific and Engineering Occupations, 1969-72

Occupation	Percent quit	Percent laidoff
Scientists:		
Agricultural	0.0680/0	0.0040/0
Biological	0.124	0.018
Chemist	0.095	0.042
Earth/marine	0.122	0.034
Physicist	0.147	0.053
Engineers:		
Aeronautical/astronautical	0.075	0.081
Chemical	0.093	0.049
Civil/architectural	0.179	0.034
Eiectricai/electronic	0.143	0.074
industrial	0.157	0.066
Mechanical	0.130	0.068
Metallurgical/materials	0.083	0.057
Mining/petroleum	0.158	0.022

petroleum engineers had the lowest incidence (2 percent).

Table C-4 reports the percentage of engineers changing occupations during the 1969-72 period. Within the selected sample, 3.6 percent of engineers changed occupations, and about 54 percent of them shifted into other engineering occupations. The greatest exodus was out of aeronautical/astronautical engineering (6.7 percent) and the greatest entrance was into mechanical engineering (9.6 percent of those changing occupations). Of all occupation leavers, 73 percent moved into what appears to be equivalent engineering or scientific occupations. Another 6 percent shifted downward to technician jobs, and the remainder shifted into a wide mix of occupations ranging from secondary teachers to laborers.

An examination of the incidence of various labor market adjustments indicates that OJT (both formal and informal) is more widely experienced across S/E occupations than any other type of market adjustment. Although to some degree I am comparing apples to oranges, the above figures are consistent with the no-

Table C-4.—Frequencies of Occupational Change by Engineering Occupation, 1969=72

Occupation	Percent changed occupations
Aeronautical/astronautical.	*0.067%*
Chemical	*0.027*
Civil/architectural	*0.018*
Electrical/electronic	*0.039*
Industrial	*0.052*
Mechanical	*0.032*
Metallurgical/materials.	*0.036*
Mining/petroleum	*0.015*

tion that OJT plays a predominate role in adjusting to technological change.

The Case of the Computer Industry

The following section is a brief summary of my recent analysis of human capital adjustments by S/Es in computer manufacturing (9). The summary begins with a cursory overview of the structure and growth of the computer industry in the United States. Subsequently, I present some empirical evidence on the relationship between technological change and OJT.

TECHNOLOGICAL CHANGE IN THE COMPUTER INDUSTRY

Soma describes the computer industry structure as it has evolved from the early 1950's. During the 1950's there were three distinct segments: the electrical component manufacturers, the computer manufacturers (mainframe assemblers, sales, and maintenance), and the end users. By the 1970's this structure became much more complex. For example, some mainframe assemblers integrated vertically into electronic component manufacturing, and independent leasing and maintenance firms were established along with software firms, computer utilities, a used computer market, and peripheral manufacturers. A study of the computer industry, therefore, requires the examination of electrical component manufacturers, the various types of hardware manufacturers, and software firms. Of course the users of computer technologies include nearly every type of enterprise.

Technological change (as defined for present purposes) primarily has been contingent on major improvements in electrical components. The transition from vacuum tube technology (used in the early 1950's) to transistor-based product lines marked a substantial advance in computer technology. This adoption in electrical components appears to have underpinned the second generation of computers—from 1959 to 1964. The third generation of computers was founded on the **development of integrated circuits which became economically competitive** in the mid-1960's. If a fourth generation exists, it is not as well defined as the previous generations. "Most companies have introduced new lines of equipment with improved technology since 1965, but there is no single technical advance to be used in specifying a new generation. In terms of circuits, the primary change has been a movement from integrated circuits to large scale integration . . . " (5).

Based on these technologies, technological changes in computer hardware have varied widely and grown substantially. Phister plots annually many of these changes over the 1955-75 period. For example, he shows that the average internal memory bytes per general practice system remained roughly constant from 1955 to 1965 but steadily increased from 1965 to 1974. Other types of measurable innovations include increases in the: storage density of magnetic-core memories and moving-head files, off-line storage capacity of magnetic tape and disk pack media, average number of moving-head files, magnetic tape drives, and terminals per system (among many others).

EMPIRICAL ANALYSIS

Exploratory interviews with personnel managers of a convenient sample of firms in the computer and electronics industry yielded two important general observations. First, formal OJT plays the predominate role in human capital adjustments for employed S/Es. Formal OJT typically takes the form of training sessions ranging in duration from 2 to 3 days to 2 to 3 months, sometimes on an intensive full-time schedule but usually on a less intensive part-time schedule. The second major observation from the open-ended interviews is that employers decide who, when, and how much training is required to meet planned production and service goals. According to the sample of personnel managers, employees who survive the industry take the training as required—''its just part of the job."

It is hypothesized that rapid technological advancement in the computer industry requires considerable OJT to keep abreast of rapid obsolescence in human capital. The probability of OJT in any given year, therefore, is a direct function of technological change. As a general index of technological **change, the change** in the rate that new computers (including minicomputers) are introduced annually is employed in the probability model below. By using an index of the change in the rate of technological advancement, I am arguing that employers respond to noticeable shifts in deciding to provide OJT. The larger the shift upward in the introduction of new technology, the larger the probability that OJT is provided. Conversely, the larger the shift downward, the larger the reduction in OJT requirements.

Annual observations on S/Es in the computer industry are drawn from the NLSSE. Observations are pooled for the **1972-75** period for which the incidence of formal OJT is reported in the survey.

Restricting the sample to S/Es working full-time year round for the entire **1972-75** period, let $P\ (OJT)_{ij}$ be the probability of receiving formal OJT in year i by individual j. The cumulative logistic function:

$$P\ (OJT)_{ij} = 1/1 + e^{-}(B_{ij}X + U_{ij})$$

is estimated by maximum likelihood. $P\ (OJT)_{ij} = 1$, if OJT was made in year i by individual j, O otherwise; U_{ij} is the error term, and

$$B_{ij}X = B_{Oij} + B_{1ij}(NMODELS) + B_{2ij}(CTOTREV) + B_{3ij}(AGE) + B_{4ij}(BS) + B_{5ij}(MS) + B_{6ij}(PHD) + B_{7ij}(OCCUP) + B_{8ij}(TENURE)$$

where:

NMODELS	=	**rate of change in number of new computer models introduced in year i-3**
CROTREV	=	**percentage change in annual total industry revenue in year i-1**
AGE	=	**age in year i for individual j**
BS	·	**1 if had bachelors degree in year i for individual j**
MS	=	**1 if had masters degree in year i for individual j**
PHD	=	**1 if had Ph.D. in year i for individual j**
occur	=	**zero-one dummy variables for engineers, computer specialists, and managers (scientists and others in benchmark)**
TENURE	=	**years employed in job in year i for individual j**

Once a new innovation is introduced to the market, there is a delay before it becomes widely adopted. Thus, obsolescence and the need for retraining becomes a function of that adoption delay. Knowing the appropriate lag of the change in the rate of introduction of new computers is problematic. Unfortunately there is little empirical evidence about the rate of diffusion of other technological advancements on which to base a judgment. Work by Mansfield, et al. **(13),** however shows that the introduction of numerically controlled machine tools has taken anywhere from **6** to 15 years to become widely adopted by major user industries. Since technological advancement in the computer industry has been particularly rapid, one would infer that the lag is considerably shorter in the computer industry than in other industries. In order to estimate the most "appropriate looking" lag, the model is tested against 1- to 5-year lags on the NMODELS variable.

RESULTS

The results of the estimated probability model are reported in table C-5. The partial derivatives of P

Table C-S.—Estimation of the On-the-Job Training Probability Model, 1972-75

Variable	Mean	Coefficient[a]	t-value
NMODELS	–2.75	0.004	1.811
CTOTREV	6.50	–0.007	–0.979
AGE	39.25	–0.015	–3.555
BS	0.59	0.157	1.291
MS	0.30	0.128	0.998
PHD	0.03	0.667	3.226
Computer specialist	0.35	0.266	3.985
Manager	0.12	0.179	1.951
Other	0.04	0.442	2.810
TENURE	6.63	0.010	1.333
Intercept		0.173	0.885
Chi square	45.55 (10 d. f.)		
N	324.00		

[a]The coefficients reported above are $\beta(\bar{P})(1 - \$)$, where β is the logit estimate and $\bar{P}$ is the mean probability of on-the-job training (= 0.386).

$(PJT)_{ij}$ with respect to each variable are given, evaluated at the mean P (OJT) (= **0.386).** Using a 3-year lag on the rate of change in the number of new models introduced annually (NMODELS), a significant positive relationship with the probability of OJT is found. The increased probability in OJT in **1972** (where the rate of change between 1968 and **1971 = –25),** is estimated to be as much as **15** percentage points. Given that the mean probability of investing during the 4-year period under consideration **(1972** to 1975) is **0.39,** the impact of technological change is apparently considerable.

No significant relationship is found between the percentage change in total revenue and the probability of OJT. This holds regardless of the lag employed.

Age shows the expected negative relationship, where the partial derivative is –0.015 per year of age; significant at the 0.01 level. As a point estimate, this indicates that a 40 year old S/E would be less likely to receive OJT than an identical 30 year old by as much as 15 percentage points. Further tests to examine the linearity of the relationship (i.e., using age in log and quadratic forms) support the inference that the training-age profile is downwardly linear.

Only for Ph.D.s does the probability of OJT differ by level of education. But here the estimate is peculiarly large, albeit, highly significant. Given the size of the estimate **(0.667)** and the fact that only **0.03 of** the sample are Ph.D.s, I find it difficult to place much faith in the estimate, On the other hand, the results suggests that Ph.D.s are especially prone to receiving formal OJT—perhaps because their functions are so closely tied to generating technological change.

The set of occupational dummy variables shows that there are substantial differences among occupations. Since any occupational classification must be compared to all others (i.e., all others, including engineers, are in the benchmark), it is impossible to estimate the

differences between any two occupations. Yet it can be inferred that computer specialists and managers retrain more frequently than engineers.

Finally, TENURE obtains an unexpected positive sign but it is insignificant at conventional levels of confidence. The positive sign does suggest, however, that OJT is more likely received later than earlier in one's tenure.

CONCLUSIONS

Using a pooled cross-section time series logit probability model, it was found that technological change has a substantial impact on the probability of receiving OJT during any given year. The results are limited, however, and must be treated as first approximations. First, the time period under study is limited to **1972** to 1975 **because of data limitations—both with respect to individual data and available indices of technological change.** Second, the pooling technique suffers from a potential violation of the assumption of independence. That is, if an important variable correlated with the dependent variable is omitted at the cross-section, pooling that omitted variable (in effect) over time results in autocorrelated error. Although the estimates would be unbiased, the standard errors would be understated.

As a first approximation, (and bearing in mind the above limitations) the results support the consensus of a sample of personnel managers in the computer industry that formal OJT plays in a crucial role in adapting the S/E labor force to changing production functions. Furthermore, the model estimates that the lag between the introduction of new computer models and subsequent training is approximately 3 years on average.

A similar empirical analysis of the linkage between postschool educational investments and technological change yielded no significant relationship. Because technological change in the computer industry is so rapid and universities cannot afford to provide training based on expensive technologies, continuing education programs do not provide a viable alternative of adjustment to technological change—at least for S/Es in the computer industry.

Programmable Automation and Labor Saving Adjustments

What Can We Expect?

The above analysis of OJT indicates that the acquisition of new skills and knowledge is widespread for the S/E labor force. My impression is that the professional S/E labor force is probably the most highly adaptable **segment of our labor force. By the very nature of S/E educational training, workers are well equipped to make adjustments to outdated skills and knowledge. Indeed one of the primary roles of the S/E labor force is to advance our knowledge and pursue the goal of technological and innovative improvements.**

Consequently, growth in programmable automation in manufacturing is unlikely to cause considerable disruption for the experienced S/E labor force. Adaptation to technological and innovative advance caused by programmable automation will come in the form of formal and informal OJT. The more rapid the developments in programmable automation, the greater will be the extent of OJT and the less likely formal education will play an important role in providing experienced S/Es with new skills and knowledge. This latter conclusion is based on what has been observed in the computer industry. Universities in general simply do not have the resources for accumulating and developing the necessary physical capital to train S/Es in the latest technologies. Because of limited resources, research and development (R&D) in programmable automation unfortunately will greatly limit universities from providing students with advanced training, which in turn will slow the reindustrialization of U.S. manufacturing.

Therefore, the potential fly in the ointment is the lack of resources available to universities to play lead roles in R&D and the education of new S/Es. The problem is that newly trained S/E graduates will not provide the manufacturing industry with cutting-edge talent. Instead, the industry will need to provide substantial training to new S/E entrants. Consequently, instead of recruiting S/Es with skills capable of satisfying immediate technical needs, manufacturing firms will experience a lag in recruiting S/Es to implement and improve new programmable automation operating objectives.

To aggravate the problem, private industry appears to be recruiting some of the best talent in S/E Ph.D.s; not only newly minted Ph.D.s but also experienced educators. The heart of this problem lies in the substantial differences between current salaries of Ph.D.s in universities visa vis private enterprise. This brain drain from the universities implies that opportunities for more widespread and advanced educational training will be retarded.

The above scenario suggests that although programmable automation will be ready technically for diffusion throughout manufacturing, the S/E labor market will not have the requisite skills to implement the technology-at least in the short run. This will hamper diffusion of programmable automation and any immediate expected improvements in productivity attributable to programmable automation.

Research Needs

If my best guess about what to expect is reasonably accurate, then appropriate social policy should focus on providing universities with the necessary resources to establish educational curricula in programmable automation. Additional resources can come from government and/or private industry. The primary research need is to examine the current and planned R&D and educational activities of higher education. The basic questions to investigate are:

1. What programs focusing on programmable automation have been established? We know, for example, that several major universities have established research centers in programmable automation; including Stanford, Purdue, Carnegie-Mellon, Massachusetts Institute of Technology, and the University of New Hampshire (among others).
2. Where have universities received resources for these programs? The above-mentioned universities have relied primarily on NSF grants, donations from corporations, and university budgets.
3. Are universities gearing up for R&D and educational programs in programmable automation?
4. What resource limitations are the universities facing?
5. To what extent is private industry attracting top Ph.D. talent? Is this recruitment causing shortrun bottlenecks in developing programmable automation curricula and R&D activities? How can universities maintain their S/E faculty in light of low relative salaries?

Answers to these questions are important not only to government policymakers but also to higher education administrators and manufacturing executives. Thus, I would recommend that OTA investigate the answers to the above set of questions. A survey of major educational institutions could provide OTA with reliable information to evaluate the above scenario. If such an assessment warrants considerable interest by the U.S. Government, then a task force composed of administrators from higher education, executives from manufacturing, and officials from government should be established. The purpose of the task force would be to design and coordinate educational efforts to train future S/Es in programmable automation.

In the next section I briefly overview several data collection efforts by NSF (Division of Science Resources Studies). Ongoing efforts by NSF in collecting and analyzing data about S/E labor markets are extensive and in depth. They are potentially very suitable for collecting the type of information I have suggested above. Although I am not recommending at this point any **additional research, data collection efforts by NSF also provide the most useful data source for monitoring how well the S/E labor force adjusts during an era of programmable automation—both in terms of new entrants and experienced S/Es.**

National Science Foundation Data Bases (see NSF)

SURVEY OF SCIENTIFIC AND ENGINEERING EXPENDITURES AT UNIVERSITIES AND COLLEGES

This survey is conducted biennially to provide information on three areas of academic spending for scientific activities: 1) R&D budgets, 2) expenditures for departmental research and instruction, and 3) capital expenditures.

SPECIAL SURVEYS

NSF also conducts special surveys. Prominent among these is the *Higher Education Panel Survey* which is conducted by the American Council of Education. The survey is conducted several times a year with the primary objective of providing quick responses to current policy questions relevant to S/E labor markets. (This survey may be especially well suited for the type of quick evaluation suggested in "Research Needs" above.)

A second example is the survey of ***Scientific Equipment in Academic Institutions.*** Its purpose is to measure the adequacy and utility of available equipment.

SURVEY OF SCIENTIFIC AND ENGINEERING PERSONNEL EMPLOYED AT UNIVERSITIES AND COLLEGES

This survey collects data about academic S/Es by field of employment and primary function.

SURVEY OF GRADUATE SCIENCE STUDENTS AND POST-DOCTORALS

The objective of this survey is to obtain data on the characteristics of graduate science and engineering enrollment at the departmental level. Data from this survey provide a base for assessing the relationship between financial support and shifts in graduate enrollments.

THE NATIONAL LONGITUDINAL SURVEY OF SCIENTISTS AND ENGINEERS

This biennial survey is a continuing longitudinal effort to maintain a comprehensive picture of the development and utilization of individuals who were part of the S/E labor force in **1969.** The survey elicits information about human capital investments, earnings, and employment/reemployment experiences.

THE NATIONAL SURVEY OF RECENT SCIENCE AND ENGINEERING GRADUATES

This survey is conducted biennially, furnishing information on graduates in science and engineering fields; including data on employment, earnings, and other labor market experiences.

THE NATIONAL SURVEY OF DOCTORATE RECIPIENTS

This is a biennial survey with the primary objective of estimating the national supply and utilization of doctoral S/Es.

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TECHNOLOGY AND LABOR

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July 27, 1982

Technology changes the way goods and services are produced and distributed—and for all its potential benefits, including creation of new jobs, technology also has destructive effects on workers and their jobs. Therefore, workers and their unions have a direct and vital interest in how technology is introduced in the workplace—to make sure people get priority over technology, to make human values prevail.

Technology often involves labor-saving operations—increased production with the same number or fewer workers. This may wipe out many existing jobs. It may raise new dangers to workers' safety and health. Of course, new jobs may also be created. New protections may be achieved for workers' safety and health. But the impact of new technology is often to eliminate some jobs, change the job content of others, change skill requirements, and change the flow of work.

Technology often causes changes in industry location—shutdowns of departments and entire plants and shifts to new locations in suburban or outlying areas and sometimes overseas. No industry is immune to such changes, which are constantly shifting the structure of skills, occupations, jobs, and earnings of American workers.

Collective Bargaining

Collective bargaining holds a vitally important role in meeting the challenges, opportunities, and dangers of new technology. There is much to be learned from past experience in collective bargaining. The flexibility of this institution, the American system of labor-management bargaining at the plant, company, and industry level, helps workers negotiate and settle with employers on reasonable and humane protections for workers against the potentially adverse effects of job-destroying technological innovation. Mature collective bargaining relationships between labor and management provide more opportunities and a sound basis for special labor-management committees to deal with adjustment to technological change within the framework of collective bargaining.

Collective bargaining can help democratize labor-management relations and humanize the workplace and work itself, including the impact of new technology on workers' jobs and earnings. Collective bargaining can provide cushions to soften the adverse impact on workers by setting up adjustment procedures and programs at the workplace. In a full employment economy—linked with adequate employment services, employment and training programs, and unemployment compensation—the disruption of workers' lives and the job displacement resulting from technological change can be minimized.

Historically, unions have responded in a number of ways to the introduction of new technology. In 1960, Sumner Slichter, James J. Healy, and Robert Livernash, reported that major determinants of union policies toward technological change are:[1]

1. the nature of the union, meaning specifically whether it is a craft or industrial union;
2. the economic condition of the industry or the enterprise, or occupation, whether it is expanding or contracting, whether the industry is highly competitive or not;
3. the nature of the technological change, the effect on jobs and on the bargaining unit, the effect on workers' skills and job responsibilities; and
4. the stage of development of the technological change and the stage of development of union policy toward the technological change.

Slichter, Healy, and Livernash distinguish five principal policies that unions adopt when faced with technological change: 1) willing acceptance, 2) opposition, 3) competition, 4) encouragement, and 5) adjustment with an effort to control use of the new technology. They note:

> The most usual policy of unions toward technological change is willing acceptance. This happens in the numerous cases in which the technological change makes little difference in the kind and degree of skill required and has little immediate effect on the number of jobs. But the gain in productivity from the change may make it attractive by giving labor improved opportunity to bargain for wage increases. Unions may be led by favorable bargaining opportunities to accept willingly technological changes that involve a mixture of advantages and disadvantages. Thus, the bargaining advantages that accompany a change requiring greater skill may lead to willing acceptance even though it greatly reduces the number of jobs.

Slichter, Healy, and Livernash go on to point out that no national union in recent years has destroyed itself by fighting technological change.

> Nor is there record of any union in recent years being able to prevent technological change by opposing it—though many unions have retarded recent changes temporarily and locally. Union wage policies appear to have been partly responsible for stimulating technological change under some circumstances and may have affected the distribution of gains. Three principal effects have been produced by union policies toward technological changes:
>
> (1) They have tended to give to the holders of jobs on the new machines or new processes somewhat higher wages relative to other workers in the same plant—in other words, they have tended to introduce distortions in the wage structure of the plant.
>
> (2) They have tended to a slight extent to cause the new techniques to be operated with excessive crews and under make-work rules.
>
> (3) They have considerably eased the hardship of displacement, partly by forcing managements to do advance planning in the introduction of technological changes and partly by giving displaced workmen an opportunity to qualify for other jobs.

[1] Sumner Slichter, James J. Healy, and Robert Livernash, *The Impact of Collective Bargaining on Management* (Washington, D. C.: The Brookings Institution, 1960), ch. 12, "Union Policies Toward Technological Change."

Using the approach developed by Slichter, Healy, and Livernash to distinguish the five principal attitudes that unions take toward technological change, Doris McLaughlin of the University of Michigan made a survey of union officials, management, and mediators and arbitrators on the impact of labor unions on the rate and direction of technological innovation.

The McLaughlin report[2] found that willing acceptance was the most common response American labor unions make to the introduction of new technology. The next most common response was initial opposition, but this was followed by adjustment, so that, in the long run, willing acceptance or adjustment were, by far, most common.

A negative union response to the introduction of technological change was invariably the result of belief that acceptance would have an adverse effect on a large or important segment of the union's membership. If the employer convinced the union's leaders that their members would not be adversely affected, or that those who were adversely affected would receive some off-setting benefit, union opposition disappeared.

The three most important variables in determining union reactions, in order of importance, were:

1. the state of the economy,
2. union leaders' perception of the inevitability or necessity for the change, and
3. the nature of the industry.

McLaughlin noted that, depending on union perception of these three variables, a fourth variable-where decisionmaking power lay—became crucial. If the international union held the decisionmaking power, a decision on how to react to the new technology would be made only on consideration of the first three variables. However, if decisionmaking power lay with local union leaders, three more variables became relevant:

4. how local union leaders perceive the impact of the new technology on the bargaining unit,
5. how local union leaders perceive the "quid pro quo" offered by the employer to the affected union members, and
6. how local union leaders perceive the impact on those union members left in the unit after the new technology is introduced.

Third-party action by mediators, arbitrators, or judges did not seem to affect the outcome, according to the report, but did appear to affect the process by which unions and management reached accommodation to the effects of the new technology. These third-party agents, as outsiders, serve a useful function in taking the heat off local union leaders "when otherwise politically delicate decisions need to be made with regard to the introduction of new technology, " the report states.

Surprisingly, labor unions are not the major stumbling block to new technology and higher productivity, McLaughlin concludes, but "employer representatives, particularly at the middle management level, were often cited as constituting the real barrier to the introduction and effective use of technological innovation. "

In 1964, the Bureau of Labor Statistics reported[3] that some of the major labor-management efforts to protect against the effects of new technology have included:

1. guarantees against job or income loss and, in some cases, against loss of supplementary benefits for varying periods,
2. compensation for employees who lose their jobs,
3. guaranteed income for workers required to take lower paying jobs,
4. provisions for retraining,
5. provisions for transfer to other plants and payment of relocation expenses, and
6. agreements to provide workers with notice of plant closings or other major changes.

Some agreements have established joint labor-management committees to recommend methods of providing for workers affected by automation. The report concluded that:

> **These arrangements typically are combined with provisions for retention of workers with greatest seniority, but in a limited number of cases, efforts are made to spread work among larger numbers of employees or to encourage early retirement of workers with relatively high seniority.**

In 1966, the Automation Commission called attention to the need for private sector efforts to facilitate adjustment to technological change including reliance on attrition, an advance notice early warning system, job counseling and job-finding assistance, training and retraining. The Commission noted the rationality of using the seniority principle in the case of layoffs and the seriousness of the need for pension and health benefits to continue during periods of unemployment. They also pointed out that technological improvements can bring more flexibility to work schedules and more leisure to employees through reduced hours of work per day, per week and per year,

'Doris B. McLaughlin, *The Impact of Unions on the Rate and Direction of Technological Innovation* (Detroit, Mich.: Institute of Labor and Industrial Relations, University of Michigan–Wayne State University, February 1979), report to the National Science Foundation, grant PRA 77-15268.

³*Collective Bargaining and Technological Change* (Washington, D. C.: U.S. Department of Labor, Bureau of Labor Statistics, March 1964), BLS report No. 266.

'Technology *and the American Economy, vol.* 1 (Washington, D. C.: National Commission on Technology, Automation, and Economic Progress, February 1966).

The record of collective bargaining response to technological change offers many examples of both success and failure, the Commission noted:

> Collective bargaining has proved to be an excellent vehicle for the effective management to change; it permits those directly affected by the change to deal with it firsthand and with a familiarity that takes into account peculiarities and problems peculiar to an enterprise. Especially in recent years, some managements and unions, occasionally but not usually with the help of outsiders, have developed, with varying degrees of ingenuity and success, plans to facilitate change."

But the Commission warned:

> Despite its many successes, collective bargaining has often failed, and sometimes has failed spectacularly, to deal effectively or even responsibly with the management of change. It has been argued, not unreasonably, that the failures are the fault of the parties, not of the system.
>
> Procedurally, the process of collective bargaining on basic issues has tended to stagnate during the life of the agreement and to accelerate frantically in an atmosphere of crisis immediately preceding contract renewal. Happily, employers and unions in a number of industries are abandoning this pattern in favor of more or less continuous discussion. Basic issues such as adjustment to technological change cannot be resolved, however, by a small team of negotiators working themselves into a state of physical and mental exhaustion for a few months every 2 or 3 years. These issues must be dealt with patiently, carefully, and above all, continuously, until satisfactory solutions emerge. This kind of bargaining calls for ability of the highest caliber on the part of leaders of both labor and management.

In the 15 years since the Automation Commission's report, with generally slow economic growth and recessions in 1969-70, 1973-75, 1980, and 1981-82, economic conditions have not been conducive to easy adjustments to technological change. The impact of new technology has become much more pervasive in the 1980's than it was in the 1960's.

It must be emphasized that it is easier to deal with adverse effects of technological change in a general economic climate of full employment. National economic policies must aim at full employment for a variety of economic, social, and moral reasons. Among those reasons we must recognize the need to facilitate successful and humane adjustments to job-destroying technology in both the private and public sectors.

Much progress has already been achieved through collective bargaining. For example, a 1981 Bureau of Labor Statistics study,[5] updating a similar 1966-67 study, presents a wide range of contract language and statistical summaries of contract language on plant movement, plant transfer, and relocation allowances, many of which relate to the effects of technological change. Agreements limiting plant movement rose from 22 percent in the 1966-67 survey to 36 percent in the 1980-81 survey of some 1,600 contracts, while worker coverage rose from 38 to 49 percent. InterPlant transfer provisions increased from 32 to 35 percent and worker coverage went from 46 to 49 percent. Agreements dealing with relocation allowances increased from 34 to 41 percent while worker coverage went up from 60 to 65 percent.

On the issues of the major technological change, work transfer, or plant closings, some major contracts have a variety of provisions.[6] For example, the United Auto Workers (UAW) -General Motors contract provides for advance notice to the union in cases of technology-related permanent layoffs, and negotiation of rights related to plant closing, department closing, and company transfer of work. Workers have the right to training for a new job in cases of technology-related permanent layoff. In the case of plant closings, department closings and transfer of work, workers have the right to bump to another job in the same plant, transfer to a replacement facility, or transfer to a new plant. They will receive preferential hiring at another plant, keep seniority with respect to fringe benefits, get moving expenses up to $1,355, take layoff with recall rights, and get severance pay.

The United Steel Workers' contract with Kennecott Copper includes a no-layoff clause and attrition protection for workers affected by technology changes which will permanently eliminate their jobs. Under this contract, workers have the right to bump to another job in the same plant or in another plant. The Transit Workers' contract with the New York City transit system and the Newspaper Guild's contract with the New York Times also have no-layoff contract protection.

The Steel Workers' contract with American Can Co. calls for a 12-month advance notice of permanent layoffs related to technological change. The United Food and Commercial Workers' contract with Armour calls for 6-month notice, and the Guild-New York Times agreement calls for 4 months. There are contracts with advance notice requirements as short as 7 days and contracts with advance notice requirements, but no specified time period.

A broad range of labor-management cooperation is already included in many other labor-management agreements with negotiated specific procedures for adjusting to technological change.

[5] U.S. Department of Labor, Bureau of Labor Statistics, *Major Collective Bargaining Agreements: Plant Movement, Interplant Transfer and Relocation Allowances,* Bulletin 1425-20, July 1981. The 1966-67 study was reported in U.S. Department of Labor, Bureau of Labor Statistics, *Major Collective Bargaining Agreements: Plant Movement, Transfer, and Relocation Allowances,* Bulletin 1425, July 1969.

[6] The following contract provisions are listed in Industrial Union Department, AFL-CIO, *Comparative Survey of Major Collective Bargaining Agreements, Manufacturing and Non-Manufacturing March 1979,* December 1979.

One method to ease the human costs of new technology is to assure advance information to workers and their unions about management plans for future innovation which will affect workers with job loss or other serious problems. Major technology changes result from management decisions taken long before the new technology is actually introduced, often years earlier. Certainly there should be long advance notice before any technological change which results in layoffs or plant shutdown. The failure of management to institute worker safety-health and environmental protections should not be the way workers learn about intended plant shutdowns or major layoffs.

An "early warning system" of advance notice helps make it possible to ease the problems of affected workers. Such "early warning" provisions have long been standard in many union contracts. With advance notice and labor-management cooperation, workers can look for or train for a new job, perhaps with the same employer in the same plant or at another location, Employer-paid retraining is an important part of any adjustment-to-innovation program.

There are other methods and techniques for labor-management cooperation to cushion adverse effects from changing technology. These include income maintenance with work and/or pay guarantees. One way is through "no-layoff" attrition to reduce the work force by natural turnover, deaths, retirements, and voluntary quits, thus protecting the jobs and earnings of those workers who remain with the company. Of course, attrition alone is not an adequate solution. "Red circle" earnings protection for workers downgraded through no fault of their own attaches a wage rate to an individual instead of to the job itself and thus protects workers against loss of income which might result from innovation-induced downgrading.

Seniority is a key principle in protecting workers against layoffs and downgradings. This rewards long service, but does much more—properly reflecting the worker's investment in the job and the company's investment in the worker. Early retirement is an option that older workers should have available when major technological change wipes out their jobs. But the option should be available as a free choice, not as a requirement. Many older workers cannot afford to retire early and others prefer to continue working.

Transfer and relocation rights and mobility assistance to workers are other ways to provide job and income protection. Within-plant and interplant transfers, relocation assistance, severance pay, pension rights and seniority protections and supplemental unemployment benefits can all help cushion adverse effects on workers and their families **when industrial innovation occurs.**

Shorter workweeks and reduced time per year on the job, including longer paid vacations and sabbatical leaves, also can ease the negative employment effects of technology.

Electrical machinery manufacturing is an industry where extensive use of robots is expected in the future. The June 1982 General Electric agreement with the International Union of Electrical Workers includes these protections for workers who lose jobs to robots and automation:[7]

> A production **employee whose job is directly eliminated by a transfer of work, the introduction of a robot or of an automated manufacturing machine and who is entitled to transfer or displace to another job shall basically retain the rate of the eliminated job for a period of up to 26 weeks.**
>
> **The company shall give the union advance notice of a minimum of six months of plant closing or transfer of work and of a minimum of 60 days of the installation of robots or automated manufacturing machine for production.**
>
> **An employee who is terminated because of a plant closing will be assisted to find new jobs and learn new skills under an employment assistance program which will include job counseling as well as job information services.**
>
> **An employee with two or more years of service who is terminated as a result of a plant closing will be entitled to receive education and retraining assistance, including reimbursement of $1,800 for authorized education** expenses.

Obviously these provisions do not constitute total protection but they offer some protection and some help to displaced workers.

Public Policy

More information is needed on the effects of changing technology on workers. Federal action is needed to set up a clearinghouse to gather information on a continuing basis on innovation and technological change and its effects on the welfare of the American people, on jobs, skills, training needs, and industry location. Few economic studies of the impact of technological change exist because there is no systematic data-gathering relating to the changing technology of American production. With more and better information, public and private adjustment programs can better avoid needless human hardship and suffering which too often result from the disruptive impact of changing technology.

Through this clearinghouse, the Federal Government could provide unions and employers with comprehensive information and service, upon request, to

[7]Bureau of National Affairs, *Daily Labor Report*, June 29, 1982.

help develop labor-management solutions for the complex problems related to the impact of technological change at the workplace.

Technology-caused economic dislocation and other kinds of dislocation—including plant shutdowns caused by corporate merger mania and by recession, job loss from trade policies and production shifts away from defense-related industry-require cooperative labor-management efforts and also national programs to deal with these complex problems. Further exploration is needed of a variety of such programs, including proposals dealing with plant shutdowns and plant relocation and with reconversion of defense-related industry.

Occupational training and retraining may perhaps help displaced workers acquire new skills and new jobs—but such new jobs may be at lower skill levels and at lower pay. Furthermore, the loss of an industry and the skills and know-how that go with that industry diminish the essential diversity and pluralism required for a healthy economy and healthy society.

In mid-1982 Congress was moving to approve new federally supported job training legislation, but the scope of the program is too small to help the millions of workers who have lost their jobs to technological change and economy shifts. The recession has sharpened union pressures to get retraining commitments from employers.[8]

Workers who lose their jobs because of plant closings may not be able to find new ones or maybe forced to work at reduced pay. Family life is often disrupted. The mental and physical health of displaced workers often declines at a rapid rate. Research over a 13-year period indicates that the suicide rate among workers displaced by plant closings is almost **30 times** the national average.[9] Such workers also suffer a far higher than average incidence of heart disease, hypertension and other ailments.

Bills to deal with this grave economic and social problem have been introduced in Congress .'" Although these bills differ in some respects, they would do much to counteract the devastating effects of shutdowns and relocations. Unfortunately, they do not address the problems caused by the relocation of governmental facilities. Among other things, these bills would:

1. require firms to provide advance notice of their intentions to close or relocate a major facility;
2. advocate programs to support troubled businesses, including incentives to promote employee ownership;
3. call for the issuance of economic impact statements and Federal investigation of the circumstance; and
4. require employers, whenever existing jobs cannot be saved, to provide minimal protections to their workers in such matters as transfer rights, relocation expenses, severance pay, pension protection, health care, and job training.

Three states—Wisconsin, Maine, and Michigan—have laws relating to plant shutdowns, and some 15 other States have proposals pending with State labor organizations pressing for action on protective plant shutdown legislation at the State level. However, because of "competitive laxity" among the States in their efforts to attract new business and "runaway" business, Federal legislation with national plant closings standards is essential,

Unfortunately, since reporting on plant closings is voluntary, the U.S. Government does not have centralized, comprehensive information on this important social and economic issue. We don't even know whether most plant closings are related to technology changes or tax incentives, to short- or to long-term economic pressures.

For labor it is crucially important to require employers to recognize their responsibilities to their employees and their communities before they shut down a plant and to provide economic protections to workers and their families who must suffer the consequence of too hasty corporate action. There is nothing radical or unusual about national legislation requiring advance notice and other worker-community protections. In other nations, private business firms—including affiliates and subsidiaries of many American firms—find they can live with laws requiring advance notice and other protections for workers and communities against the adverse effects of economic dislocation and plant shutdowns.

In terms of international comparisons, Sweden requires **6 months notice** where more than **100** workers are involved, **4 months notice where 26 to 100 workers are involved, and 2 months notice where 5 to 25 workers are involved. Under Swedish law, no dismissals may take place until the unions have been contacted and granted an opportunity to negotiate concerning the issues and consequences of the dismissals. In the United Kingdom, 90-day notices** must be given where **100** or more workers are involved and **30** days in plants employing *10* to **99** workers. Failure to communicate with the unions and to give the appropriate

[8]For example, see "Retraining Displaced Workers: Too Little, Too Late?" *Week,* July 19, 1982, pp. 178-185.

[9]Barry Bluestone and Bennett Harrison, *Capital and Communities: The Causes and Consequences of Private* Disinvestment (Washington, D. C.: Progressive Alliance, 1980), pp. 78-82. The health-unemployment link is one of the most clearly documented social research conclusions, e.g., Harvey Brenner, *Estimating the Costs of National Economic Policy Implications for Mental and Physical Health, and Criminal Aggression,* Joint Economic Committee, U.S. Congress, Oct. 26, 1976.

[10]For example, see 96th Cong. bills H.R. 5040, introduced by Congressman Ford of Michigan; S. 1608, introduced by Senator Riegle of Michigan; S. 1609, introduced by Senator Williams of New Jersey; and S. 2400, introduced by Senator Metzenbaum of Ohio.

notice can make the employer liable for continuing pay of the workers during the required notice period. In France, Greece, and the Netherlands, prior to making large-scale dismissals, the firm must have permission of the government to lay off the workers and in actual practice the advance notice period is as long as half a year to a year depending on the specific circumstances.

These examples indicate that advance notice is a practice with which firms can live. It must also be remembered that in most foreign countries the benefits paid workers are generally two-thirds of lost earnings for up to 1 year after the layoff.

Unfortunately, in the United States, there area number of tax advantages provided for corporations which close down even viable, moneymaking plants. Congress should look into these plant closings very carefully to determine if there is indeed an array of tax incentives encouraging businesses to close down plants. Legislation must be created which will stop such incentives and will prevent tax-related plant shutdowns. Legislation must also be created which will establish basic job and income protections for workers and protection of workers' pension and health care and other benefits, to deal in an effective and humane way with the economic and social dislocation resulting from plant closings.

Industrial Democracy

The potential for misusing technology is great, but the possibility of human progress through the wise and humane use of technology is equally great. The opportunity for new technology to be introduced with minimal social disruption will be greatly enhanced if workers and employers have an equal opportunity for discussion and joint decisionmaking on the subjects of changing technology and the quality of working life.

Collective bargaining, an established institution in our democratic society, has been a fair and workable process for joint labor-management decisions on wages, working conditions, and other major issues. It is therefore a logical mechanism for increasing the involvement of workers in such areas of decisionmaking as adjustment to new technology.

New technology and rising expectations are forcing transformations in the workplace. Applications of new technology should be humane for workers as well as profitable to business. Human and social values must be more highly valued in the production process, not only when **the process is producing goods and services, but** also when it is producing cultural and social values and leisure and unemployment. The human desire for greater autonomy and greater participation in decisionmaking on the shop floor, in the corporate boardroom, and in national economic policymaking must receive higher priority. Improvements in the "quality of work life" (QWL) include a broad range of issues, such as better occupational safety and health, as well as work-organization, work environment, and longrun investment, employment and training decisions, and the introduction of new technology. These QWL issues are logical subjects for joint labor-management negotiation and decision. But employers must not use QWL as a disguise for union-busting.

Irving Bluestone, a former UAW vice president, has been a strong proponent of increased worker participation in corporate decisions. He warns:[11]

> **The joint union-management programs that are in existence have not yet proven themselves in any permanent sense. They must be subject constantly to review and change as management, the union, and the workers learn by doing. Although it is not possible to set forth a precise blueprint to ensure the successful participation of workers in the decision-making process, experience already indicates certain criteria that are basic:**
>
> - **The programs should be voluntary. Workers must have the free opportunity to decide whether or not to participate in the program. To order compulsion is to invite resistance and failure.**
> - **Workers should be assured that their participation in decision-making will not erode their job security or that of their fellow workers, that they will not be subject to 'speed up' by reason of it, and that the program will not violate their rights under the collective bargaining agreement.**
> - **Workers should genuinely experience that they are not simply adjuncts to the tool, but that they are bent toward being creative, innovative, and inventive plays a significant role in the production (or service) process.**
> - **Job functions should be engineered to fit the worker; the current system is designed to make the worker fit the job on the theory that this is a more efficient production system and that, in any event, economic gain is the worker's only reason for working. This theory is wrong on both counts.**
> - **The worker should be assured the widest possible latitude of self-management, responsibility, and opportunity for use of "brainpower." Gimmickry and manipulation of the worker must not be employed.**
> - **The changes in job content and the added responsibility and involvement in decisionmaking should be accompanied by an effective reward system.**
> - **Workers should be able to foresee opportunities for growth in their work, and for promotion.**
> - **The role of workers in the business should enable them to relate to the products being produced or the services being rendered, and to their meaning in society; in a broader sense, it should also enable them to relate constructively to their role in society.**

[11] Irving Bluestone, ch. 12, "Emerging Trends in Collective Bargaining, " in *Work in America: The Decade Ahead,* Clark Kerr and Jerome M. Resow (cd.) (New York: 1979), Van Nostrand Reinhold, pp. 249-50.

Quality of Work Life

The conflict theory of labor relations is the soundest basis for worker representation, worker participation, and worker gains. Conflict is institutionalized in our political system. Conflict is institutionalized in our legal system. Conflict is institutionalized in our economic system. And we have institutionalized conflict in labor-management relations through the American system of collective bargaining.

But the adversary role, which is appropriate to the conflict of collective bargaining, should be limited to the period of negotiation—and during the life of the contract, the adversary relationship can very logically and appropriately be replaced by cooperation aimed at maximizing the potential success of the enterprise, the company, or the establishment. The labor relations cycle should be one of periods of conflict during the negotiating period followed by the longer contract period of cooperation.

Collective bargaining is basic and fundamental to honest labor-management cooperation—and such cooperation can be mutual self-help supplement to collective bargaining. Committees that exist outside collective bargaining or try to take over the process of collective bargaining are not to be trusted.

Labor unions today jointly participate with management in thousands of safety committees, apprenticeship committees, communitywide labor-management committees, quality of work life committees, quality circles and other joint labor-management efforts. As a result, labor-management committees are joining together to deal with matters of mutual interest such as foreign trade; Federal, State, and local programs; community philanthropic purposes; and revitalization and strengthening of their industry and their community as well as those committees which give workers a direct voice in the issues of the workplace, including investment and innovation with new technology.

But, only the collective bargaining stature of their unions establishes workers as real partners in those labor-management committees. Any action that weakens a union, distorts the balance in its relationship to management, or its ability to represent its membership, will damage that union's ability and desire to participate in committees of any kind with a particular management.

Any program which strengthens the union's ability to grapple with the new issues union members want addressed, including technology change issues, any program which holds out real promise for the expansion of workplace democracy, ought to be grasped, minutely examined for flaws, reshaped as necessary, polished, and put in place—and then watched very carefully.

QWL programs in the United States have taken many different forms and appeared in many different guises-participatory management, employee involvement, shop-floor democracy, consultation schemes, labor-management committees, quality circles, autonomous work groups, QWL **teams, profit-sharing incentive structures, etc.**

As a tool used toward labor's basic goals, these QWL programs can develop skill improvement programs, more flexible working schedules, greater job security and promotional opportunities, along with many other matters of great importance to the members we represent. So, other things being equal, unions have every reason to encourage and cooperate in any enterprise that will work to those constructive ends, for the benefit of workers and management alike.

But hard experience has taught us to look for pitfalls. Too many employers are more interested in programs that offer cosmetic changes that try to fool the workers into believing that management really cares about them, in spite of low pay and bad working conditions.

Too many union-busting "consultants" are promoting these QWL programs as an alternative to worker participation through trade unionism. That way, without the protection of a union contract, any concessions to workers can be revoked as easily as they were given. At best, the QWL group concept poses a problem to the labor movement because of the potential that exists for management to penetrate and influence small, informal work groups and bust unions.

For strong unions, able to insist on an equal and active voice in how the QWL program works and able, if necessary, to veto actions that aim at subverting its bargaining position, these are not insuperable problems. That accounts for the general acceptance of QWL programs by such dominant and secure unions as the Auto Workers, Steel Workers, and Communications Workers. Even they have sometimes had to take strong action to prevent their employers from using the programs for company propaganda in bargaining situations.

Other unions are in a more difficult posture. They have organized only a piece of the action—the other facilities of the same firm unorganized, under contract with another union, or a mixture of both. Here management more often controls the introduction and implementation of technology and QWL programs. Sometimes, in fact, they move ahead to new technology with major layoffs or plant closings with barely a nod to the union.

In doing so, they establish a carefully orchestrated organizational and communication link with the em-

ployees that can bypass or attempt to supplant the union. In part, this accounts for the more antagonistic response of unions which have only bits and parts of different firms and thus more limited bargaining leverage.

QWL programs, under whatever name, can be of tremendous help in facilitating the dealing with the larger issues of collective bargaining, including wages and working conditions and the job impact of new technology. At the same time, QWL programs can deal with other less visible but basic issues that affect the individual at the workplace.

Labor has no intention of allowing management to co-opt any of these basic issues. But dealing with QWL programs will present our unions with immense problems of educating our members—training and retraining of shop stewards and business agents; giving attention to the overall coordination of QWL programs plant by plant, employer by employer, and individual by individual; and developing at national staff levels the technical expertise to assist in the negotiation of QWL programs and in their development and maintenance; and resolving problems relating to sharing technology's benefits; and deciding what are necessary agreements and conditions before entering into QWL programs.

Every union must continue in every way possible to assert its rights and the rights of its members to acceptance as legitimate equals in a partnership with management, with collective bargaining as the essential foundation for labor-management cooperation.

We recognize the valuable contribution that properly constituted and equally balanced labor-management programs can make in fulfilling the American trade union member's desire for individual recognition, dignity, safety, quality of work life, and job security.

To that end, unions will cooperate with managements that recognize and support the right of workers freely to join unions of their choice and who demonstrate willingness to work with unions as equal partners in all areas that affect their members' interests, including the impact of technology.

But unions will reject, as a dangerous fraud, all efforts to use specious programs and rigged committees to undermine unions, divert attention from the real needs of workers, and weaken enforcement of the Nation's labor laws.

Conclusion

Workers and their unions have reasonable, understandable, and legitimate concerns about loss of jobs, loss of income, and loss of life and health. If these concerns are met adequately and effectively, workers will be much more willing to accept and adjust to changing technology.

There are no simple solutions to the task of protecting workers against the adverse impacts of changing technology. In thousands of labor-management contracts covering millions of workers in both the public and private sectors, unions and management have adopted a wide variety of provisions to cushion workers against these adverse impacts. These provisions fall into a few general categories—job protection, income protection, safety and health protection, retraining, and relocation assistance. The specifics include attrition or no-layoff protection, early warning of technological change, seniority protections, early retirement opportunities, "red circle" pay protection, shorter workweeks or work-years, relocation rights to follow transferred operations, severance pay, negotiated safety-health protections supplementing safety-health laws and regulations, and many other specific labor-management collectively bargained responses to technological change.

Without full collective bargaining—no matter how enlightened or benevolent management may be—working men and women simply don't have a sense of participation in the basic decisions which govern their jobs, their income and their lives. Collective bargaining is essential to help workers share the benefits of technological progress and help workers to meet the challenge of technological change with a minimum of social and human dislocation.

LABOR= MANAGEMENT RELATIONS IN AN ERA OF PROGRAMMABLE AUTOMATION

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July **27, 1982**

Introduction

Currently we know very little about the impact of programmable automation on labor-management relations. One gets the general impression that the impact to date has been relatively small, except on a handful of occupations and industries. The potential for dramatic growth in the utilization of programmable automation, however, is generally acknowledged, albeit, the timing of rapid diffusion remains iffy. The potential for growth raises a number of important questions about labor-management adjustments during an era of programmable automation. First, we must ask: What shapes the decisions of employers to invest in programmable automation? Will unions impede the diffusion of programmable automation and to what degree (if any)? What impact will unions have on the lag between the introduction of commercially available programmable automation and its diffusion in manufacturing? Simultaneously, we must **ask: What** will be the degree of displacement of workers? What happens to displaced workers? What proportion will be retrained by employers? How many will be laid off? What kind of changes in work rules will unions seek? What kind of changes will unions gain? Will white-collar workers seek union representations?

Answers to these questions require in-depth research. Toward developing a research design, I begin with an overview of the current utilization of robotics in manufacturing and the extent of collective bargaining. I then discuss several collective bargaining issues relevant to an understanding of labor-management relations and the utilization of robotics. Subsequently, I lay out a research agenda, including a theoretical explanation of collective bargaining, implicit model specifications, and data collection.

Programmable Automation and Collective Bargaining in Manufacturing

Although programmable automation encompasses more than robotics, it is this form of programmable automation that most directly impacts on blue-collar work forces and, thus, existing union-management relations. From a research design perspective, worker displacement caused by the introduction of robots can be more precisely quantified than say, for example, displacement caused by the implementation of computer-aided design techniques. Furthermore, firms and plants utilizing robots can be identified.

Currently, robots are capable of performing tasks associated with a handful of occupations. According to the Robotics Institute of America (RIA), there were fewer than 5,000 robots in use in the United States in **1980. Table C-6 reports the estimated number of robots by broad occupational application (17).**

The type of broad occupational categories most vulnerable to replacement by robot applications are heavily concentrated in the metalworking industries (1). Table C-7 lists the basic metalworking industries by 2-digit Standard Industrial Classification (SIC) code, the number of unions representing workers within an industry, and the estimated union membership by percentage category.

It can be seen readily that metalworking manufacturing is heavily unionized and by a fairly large number of different unions. Table C-8 identifies some of the national unions that have been active in organizing drives in metalworking industries during 1980.

Time restraints in preparing this report have not allowed me to investigate the scope of contractual agreements pertaining to programmable automation. However, using the Bureau of Labor Statistics' (BLS)

Table C-6.–Robot Usage and Identification of Applications, 1980

	Welding	Machine loading, unloading	Foundry	Painting/ finishing	Assembly	Other
Number of robots	1,500	850	840	540	100	600

Table C-7.—Identification of Metalworking Industries and Extent of Unionization

Industy	SIC	Number of unions	Percent in industry unionized
Primary metals	33		50-75
Fabricated metals	34	28	50-75
Machinery (except electrical)	35	16	25-50
Electrical/electronic equipment	36	14	50-75
Transportation equipment	37	16	75-1oo

SOURCE: Bureau of Labor Statistics, *Directory of National Unions and Employee Associations, 1975*, Bulletin 1837.

Table C-8.-Unions Representing Workers in Metalworking Manufacturing Industries[a]

1. Allied Industrial Workers of America (AIW)
2. Aluminum Workers international Union (AWU)
3. Automobile, Aerospace, and Agricultural implement Workers of America (UAW)
4. Boilermakers, Iron Shipbuilders, Blacksmiths, Forgers, and Helpers; International Union (BBF)
5. Carpenters and Joiners of America; United Brotherhood of (CJA)
6. Chemical Workers Union; international (ICW)
7. Clothing and Textile Workers of America; Amalgamated (ACTW)
8. Communications Workers of America (CWA)
9. Electrical Workers; International Brotherhood of (IBEW)
10. Electrical, Radio, and Machine Workers of America United (UE)
11. Electrical, Radio, and Machine Workers of America; International Union of (IUE)
12. Engineers; international Union of Operating (IUOE)
13. Furniture Workers of America; United (FWW)
14. iron Workers; international Association of Bridge Structural and Ornamental (BSOIW)
15. Laborers; international Union of (LIU)
16. Longshoremen's and Warehousemen's Union; international (ILWU)
17. Machinists and Aerospace Workers; international Association of (IAM)
18. Marine and Shipbuilding Workers of America; industrial Union of (IUMSW)
19. Metal Polishers, Buffers, Platers, and Helpers; international Union (MPBP)
20. Molders and Allied Workers Union; International (i MAW)
21. Oil, Chemical, and Atomic Workers; international Union of (OCAW)
22. Painters and Allied Trades; international Union of (IUPAT)
23. Paperworkers; United international Union (UPI)
24. Plumbing and Pipe Fitting industry; United Association of Journeymen and Apprentices (PPF)
25. Service Employees; international Union (SEIU)
26. Sheet Metal Workers' international Association (SMW)
27. Steelworkers of America; United (USA)
28. Teamsters, Chauffeurs, Warehousemen, and Helpers of America; International Brotherhood (TCWH)

[a]The above list of unions was taken from NLRB union election files. The unions (and others) were involved In union representation elections in 1980 in the metalworking industries (SIC 33-38).

data base on union contracts ***(Characteristics of Major Collective Bargain@ Agreements),*** an **examination of recent contracts negotiated by unions in manufacturing would reveal how unions alter the scope of collective bargaining as programmable automation becomes** more widely applied.

A glimpse at contracts and various publications of the UAW, the USW, the IUE, and the IAM indicate that joint union-management committees have been established to address the general issue of productivity and the specific issue of technological change. A central purpose of these committees is to address in advance impending technological change: how to prepare for changes in the production process and how to mitigate its impact on the work force. Below I discuss the set of alternatives that unions and employers are likely to consider. One can only imagine that the scope of contractual agreements will change as more workplaces apply programmable automation to the production process. I propose below that we examine these contracts and the undertakings of joint union-management committees in order to understand more fully how labor-management relations cope with the application of programmable automation.

Current Collective Bargaining: Relevant Issues

In the following section I discuss several issues that are especially relevant to understanding union-management relations. My intention is to describe briefly some important parameters that help set the stage for my subsequent discussion of collective bargaining in an era of programmable automation.

Concession Bargaining

The current mood and trend in collective bargaining in manufacturing differs substantially from the past. Due to a deep recession and growing international competition, unions and employers have begun making concessions in wages, benefits, and work rules. Concessions by unions have covered wage and benefit packages and, to some degree, restrictive work practices. Concession bargaining is being witnessed in many places of employment—well beyond the highly publicized automobile, agricultural implement, rubber, electronic machinery, and ongoing steel negotiations. A recent mid-May poll by Louis Harris & Associates of 600 large corporations found that 26 percent of the unionized firms had obtained wage and benefit concessions in recent negotiations (4).

Employers, likewise, have had to make concessions—albeit types of concessions that do not lend themselves to easy pecuniary estimation. These concessions have included more union and worker input into management decisions and a variety of security provisions (e.g., added SUBS and reversals or postponement of plant closure decisions).

Several points can be made about the current concession bargaining. First, the recession itself would not have precipitated these concessions. The recession merely brought the longrun ills of some major industries to a head. The surge of foreign competition is the cause of the ongoing decline in much of U.S. manufacturing. Consequently, collective bargaining is beginning to address the long-term livelihood of many industries.

Second, concessions are being made by both unions and employers. This suggests that unions in these manufacturing industries are not ipso facto in weaker bargaining positions than employers. Instead, the industry is in a state of demise and, consequently, both employers and unions need to change standard operating procedures.

Third, job security has become the major bargaining chip. Rank and file have insisted on additional forms of job security (or monetary cushions to displacement) as the quid pro quo for concessions. Job security issues will continue to hold the limelight in further bargaining—primarily due to the longrun impact on existing employment in manufacturing; both in the potential reduction of existing jobs and in requiring major changes in the structure of work.

Programmable automation, therefore, will be viewed by labor much like foreign competition is viewed—as a threat to longrun employment. Job security, in turn, will be the bargaining chip for cooperation with management in restructuring hard-hit industries. In order to maximize the utilization of programmable automation, unionized employers will have to higgle and haggle over job security provisions.

Legal Requirements of Collective Bargaining and the Issue of Programmable Automation

Union-management relations have been shaped substantially by the National Labor Relations Act (NLRA) and any departure from the legal duty to bargain in good faith is highly unlikely. The National Labor Relations Board (NLRB) is the regulatory agency charged with the interpretation (along with the courts) and application of NLRA. It has laid down the ground rules (albeit foggy ones at times) to protect both parties from unfair labor practices.

In particular, the NLRB has attempted to delineate mandatory bargaining subjects (i.e., the subjects and issues for which the parties must negotiate in good faith). Good faith bargaining requires discussion but not necessarily concession to either party's demands. However, the NLRB generally has interpreted the lack of compromise as evidence of bad faith bargaining. Mandatory subjects fall under the heading of wages, hours, and other terms and conditions of employment. Ever since the landmark Supreme Court case of ***Fibreboard Paper Products v. NLRB (1964),*** the NLRB has interpreted such issues as subcontracting and plant closures as mandatory bargaining subjects. Until 1972 (Summit Tool Co. Case), employers had the legal responsibility to negotiate in good faith about decisions to subcontract (where such subcontracted work was previously done by current employees) and close plants. The Summit Tool Co. Case appears to allow employers to make unilateral decisions to close plants but still requires employers to negotiate in good faith about the displacement effects of plant closures.

The question to raise is, what will the NLRB require in terms of good faith bargaining when workers face displacement by programmable automation? It appears that if employers close plants and resort to subcontracting previous in-house production, they will be obligated to negotiate with unions—at least about the impact of these decisions on labor. It is difficult to second-guess the NLRB since: 1) it is not clear to what extent employers will close plants and/or subcontract, 2) the complexity of cases leads to unclear precedent and, thus, case-by-case resolution, and 3) the changing make-up of the Board leads to inconsistency in the interpretation of unfair labor practices (10).

Although it is unclear what impact the NLRB will have in resolving disputes over programmable automation, it is clear that NLRB governance of labor-management relations will help shape labor-management relations affected by programmable automation. It is also clear (given the enormous workload of the NLRB) that the typical long delay in NLRB conflict resolution will add to the transitory problems we might anticipate as we move into an era of programmable automation.

Union Organizing Activity

Table C-9 provides a description of union election activity since 1950. Column 1 shows that the percent of workers unionized in the nonagricultural labor force has declined steadily since 1955—from a high of 33 percent to the present low of approximately 24 percent. Part of this decline is attributable to a long-term drop in union success in representation elections; from a high of winning 75 percent of elections in 1950 to the current low of winning only 46 percent of elections. Concurrent with increased election losses has been a substantial drop in the average size of work units holding elections; from 519 workers in 1950 to only

Table C-9.—Annual Observations on Selected Parameters of Union Representation Elections

Year	(1) Percent of the nonagricultural labor force unionized	(2) Percent of elections won[b]	(3) Average unit size[b]	(4) Percent manufacturing	(5) Percent consent[b]
1950.	31.5	74.5	158.5	39.0	(c)
1955	33.0	65.3	122.4	38.6	42.6
1960	31.5	58.6	75.9	36.6	42.2
1965	28.5	60.2	70.0	35.6	46.9
1970	27.3	55.2	75.4	33.2	26.5
1971	27.0	53.2	70.1	31.8	23.1
1972	26.4	53.6	66.3	31.6	20.2
1973.	25.9	51.1	57.8	31.8	16.3
1974.	25.8	50.0	61.5	31.2	14,7
1975.	25.3	48.2	66.3	29.4	11.6
1976.	24.5	48.1	55.0	29.4	10.4
1977.	24.1	46.0	60.2	29.2	8.9
1978.	24.0	46.0	57.3	29.2	7.9

[a]Data are for calendar years.
[b]Data are for fiscal years.
[c]No comparable figure available for 1950.

SOURCES: Columns2,3,and 5aretaken fromvariousannual reports oftheNLRB.Column4 Isadoptedfromthe 1979 *Handbook of Labor Statistics.* Column 1 Is adoptad from the *Directory of National Unions and Employee Associations,* 1979.

57 workers in 1978. Obviously, this has had a substantial affect on total union membership. Column 4 presents the percent of workers employed in manufacturing, The loss in manufacturing employment is widely cited as a leading cause in the decline of union membership, primarily because manufacturing has been a historic stronghold for the union movement. **A** recent study of union elections over the **1970-78 period shows that roughly 28 percent of all private sector elections** were held in manufacturing industries and that, on average, workers were more likely to vote against union representation (all other things **held constant) than their counterparts in nonmanufacturing industries (19).**

Stepped-up employer resistance, however, has perhaps had the greatest impact on union representation elections. Employers, for example, rarely consent to union elections today. Instead, employers have been campaigning actively against union representation. For instance, using the percent of elections consented to by employers, column 5 shows that consent elections have dropped dramatically from a high of 47 percent in **1965 to under** 8 percent by 1978. Recent studies find a large negative and highly significant relationship between not consenting to elections and those election outcomes (9,19).

Another area of interest is white-collar unionization. Chamberlain, et al. (7), report that as of 1976, roughly **18 percent of the membership in national unions was white-collar (professional-technical, clerical, and sales workers). That figure represents an increase in white-collar unionization in recent years. For instance,** in **1960 only 12 percent of national union membership was white-collar. This reflects an increase from 2,200,000** union members in 1960 to 3,850,000 in 1976. If membership in employee associations is added to union membership, the proportion of members from white-collar occupations becomes **27 percent. Cooke (9) also finds** in an analysis of private sector elections in 1979 that both professional-technical and clerical-sales work groups were much more likely to vote for union representation than blue-collar workers voting in representation elections. However, it should also be noted that only 13 percent of **1979** elections involved primarily white-collar work groups.

Several important points can be drawn from the above discussion. First, the union movement in the private sector has been experiencing a long-term decline in its relative power–at least as proxied by membership figures. Second, the relative bargaining power in manufacturing has experienced the greatest slippage. Third, employer resistance to further union organizing has increased dramatically over the last 15 years. Finally, white-collar unionization has been increasing and remains a potential growth area for the union movement.

Collective Bargaining in an Era of Programmable Automation: A Research Agenda

Absent one of those funny little crystal balls, the task of anticipating the impact of programmable automation on labor-management relations will require more in-depth and sophisticated research than is currently available. In the following section I sketch out a general theory of collective bargaining. I then raise a set of questions about the impact of union-management relations. Subsequently, I develop a set of implicit models to answer these questions. Finally, I discuss data collection issues and propose a research plan.

A General Theory of Collective Bargaining

Dunlop (11) advocates the use of a systems framework in the general analysis of union-management relationships. His framework encompasses three broadly defined actors: 1) workers and their representatives, 2) management, and 3) interested government agencies (the NLRB for present purpose). These actors interact within a set of environmental constraints (technological, economic, and sociopolitical) to establish the rules of the work relationship; both pecuniary and nonpecuniary. Although Dunlop's framework is based on a historically observed set of relationships, he fails to breathe any life into the framework. A suitable theory, however, requires some underlying motivator(s) that helps explain and predict behavior. My general intention here is to utilize Dunlop's set of actors, but make them dynamic and explain their interaction within the environmental context.

Theoretical analyses of negotiations are based on the conceptual idea that bargaining "power" determines the outcome(s) of negotiations or, more generally, union-management relations. Concerned primarily with the ability of unions to raise wages, Pigou and Hicks **(16,13) define bargaining power as the ability of unions to increase wages above competitive wage levels. This concept of bargaining power has become popularly known among economists as the union's "monopoly power" to raise wages (20). Chamberlain and Kuhn (8) suggest a broader definition of power that encompasses more than wage gains: power is the ability to secure some agreement that otherwise would not be granted. This latter definition is more appropriate for our present** purpose. **In the simplest context, unions (employers) use power to force employees (unions) to agree to sets of work rules.**

Since power is primarily the ***means*** **of attaining some underlying goal(s), one needs to examine** more closely the central goals of the parties. It would seem reasonable to believe that unions, employers, and government agencies act under some premise of utility maximization. Although utility maximization offers an underlying motivator (i.e., maximizing behavior), it does not lead us to what actually motivates parties; except "whatever motivates the parties" (i.e., utility). Unless the researcher assumes what utility represents (e. g., profits, wages, etc.), the researcher cannot model very well any cause-effect relationships. Since the analysis of industrial relations issues encompasses economic, sociological, political, and psychological relationships, we need to establish a motivating principle which is amenable to incorporating such a complex array of factors.

I argue here that unions, employers, and the NLRB attempt to "optimize control" over employment relations. For unions (acting as the voice of workers), optimization of control over employment relations includes, for example, increasing job security and minimizing employer discretion with respect to wages and benefits, work assignments, displacement, and worker discipline. Optimization of control, however, does not mean that unions want complete responsibility for managing employment relations. Instead, unions want to maximize control up to the point where their members' employment prospects are not jeopardized through massive layoffs or business closures. In contrast to union optimization of control, employers want near unilateral control of all decisions affecting employment relations. Obviously, unionized employers have given up substantial control of the work rules. The optimization thesis holds that unions and employers are motivated to wrestle back as much control as possible; which implies that any state of equilibrium is short-lived. Such an optimization principle, therefore, places unions and employers in a natural state of conflict (although not necessarily in a destructive one).

During negotiations both unions and employers draw on their respective bargaining power to wrestle control from one another. Under the thesis that bargaining power determines negotiation outcomes, the sources of bargaining power must be examined. But first, bargaining power should be defined in relative terms since union and employer willingness to use potential power is a function of the perceived net gain (i.e., total benefit minus total cost) associated with using that potential power. For instance, a **union's** willingness to endure a strike to force an employer to agree to a change in a contract is dependent on the perceived net gain to the union of such a strike. Likewise, an employer's willingness to take a strike to avert signing the change in contract is dependent on the perceived net gain associated with taking a strike. In defining relative power, Chamberlain, Cullen, and Lewis (7) argue that:

> **Only** if **the cost to** management **of not** agreeing **to the** union's **terms exceeds the cost of** agreeing with them, and if **the cost to the** union **of not** agreeing to management's **terms is less** than **the cost of** agreeing **to** them, **does the** union's bargaining power **surpass** that **of the** management.

Such a definition of relative power is dependent on the size of the demand, however. For example, if a union's demand is for a 30-percent increase in "costs" to the employer, the union's relative power is less than if the demand is only **10 percent. This implies that unions and employers will** be more successful in negotiating contract changes as the cost of change becomes smaller.

The sources of relative power are determined by an array of economic, technical, legal, organizational, and sociopolitical factors. As any factor changes (or differs across firms), the relative bargaining power changes (or differs across firms). The set of implicit models described below are derived by focusing on parameters of the various sources of relative power. This set of structural equations is designed to provide answers to some basic questions about union-management relationships in an era of programmable automation.

Model Specification: Implicit Models

At this stage of the analysis I formulate several implicit models; models that begin to establish the conceptual understanding of cause-effect relationships between the diffusion of programmable automation and union-management relations. Explicit empirical specifications detailing functional form and variable measurement will require considerable additional effort.

Based on a theory of control optimization, any change in the work rules attributable to programmable automation will be a function of the employer's bargaining power visa vis the union's bargaining power. Stated algebraically,

Work Rules = f (POWm/POWu)

where POW_m = power of management and POW_U = power of union. As discussed above, the relative power of the parties depends on the sources of power and the perceived cost of the change in work rules. Thus,

POWm/POWU = f (sources of power + cost of change)

The utilization or diffusion of programmable automation (which can be viewed as a change in work rules), therefore, becomes a function of relative power:

Diffusion = f (Powm/Powu)

Similarly, a union's response to the utilization of programmable automation is a function of relative power:

Union Resp. = f (Pow_m/Pow_u)

Several of the questions raised in the introduction basically ask: how will unions influence the diffusion of programmable automation? In effect, we want to test the hypothesis that a union's response influences diffusion. The dependent variable, therefore, is the diffusion of programmable automation. Diffusion can be evaluated as: 1) the decision to invest, or 2) some measure of the amount of utilization (e.g., number of robots), and / or 3) the lag in diffusion. The dependent variable can be evaluated at firm or industrywide levels.

Our theory implies that the diffusion of programmable automation increases as the relative power of management rises above the relative power of the union, and conversely. Since relative power is a function of the perceived cost of the change of work rules plus sources of power, relative power varies as the cost of the pending change varies and as the parameters of the sources of power vary. Consequently, our analysis focuses on the cost of proposed changes in work rules as well as the parameters of sources of power.

We can begin by postulating that the diffusion of programmable automation is a function of: 1) the union response to proposed or anticipated utilization of programmable automation, plus 2) a vector (X) of other variables.

Diffusion = f (union response, X)

Our theory says that the union response will be a function of the cost of proposed changes and its source of power.

Union Resp. = f (cost of changes + sources of power)

Thus, everything else constant, as the cost to a union of the application of programmable automation increases, the more negative the response of the union. **As** discussed in the section about concession bargaining, job security becomes the central issue and the primary bargaining chip in negotiations. At the extreme, for example, if displaced workers are laid off (and say without severance or relocation pay), the cost to the union in membership and status is quite high. Of course, the greater such layoffs, the greater the cost to the union. Under these circumstances the union response will be strongly negative to the diffusion of programmable automation. At the other extreme, where, for example, all displaced workers are retrained or placed in alternative and equivalent jobs, the cost to the union is negligible: causing no negative response by the union (except perhaps to seek the establishment of a joint union-management committee to prepare for future diffusion).

Under the negative response scenario, (and again, everything else constant) the union will attempt to negotiate work rules protecting its membership. Thus, the union will attempt to increase the cost to the employer of making changes in working rules. One can imagine a wide range of proposals at the bargaining table, including: 1) guarantees of employment (perhaps tied to years of seniority); 2) restrictions on timing of the implementation of programmable automation (e.g., implementation would be tied to normal work force attrition or requirements of advanced notice); **3) retraining** requirements; **4) postponement of plant closures and subcontracting; 5) cushions to layoffs (e.g., severance, relocation, or SUB payments, and early retirement** schemes); **6) reduction** in work hours; and 7) union shop requirements covering newly created jobs.

Holding constant the cost of management's proposed changes in work rules, we can now consider the sources of power that determine the union's ability to negotiate protective work rules. It is hypothesized that the greater the union's power, the more successful it will be in negotiating protective work rules, and the more costly it becomes for management to change work rules (i. e., utilize programmable automation).

Sources of power are gained or lost according to variation in the economic and technological context of the firm, union organizational strength, legal constraints, and the sociopolitical environment. With respect to the economic context, the power of the union varies with: 1) labor costs (e.g., wages, labor cost per unit produced, wage bill / total cost, etc.); 2) the product market (profits, sales, industry concentration, insulation from foreign competition, etc.); and 3) the labor market (employment growth in firm or industry, layoffs, unemployment, etc.) As an illustration, in a firm or industry experiencing a loss in sales, declining profits and employment, and a growing threat from international competition, the union's sources of power are diminished as well as its ability to shift the cost of work rules to the employer.

With respect to the technological context, the more the production process is amenable to the utilization of programmable automation and / or the less strategic the work force in the production process, the less the power available to the union. This relationship is analogous, in part, to the study of union strike activity, whereby union strike activity is reduced as the production process can be manned temporarily by nonunion supervisors and workers.

Everything else constant, organizational strength plays a role in determining the union's strength. Worker unity in supporting leadership initiatives, the willingness of workers to endure strikes, the financial resources of the union, membership size and extent of organization, and negotiation skills are all positively related to union power.

The NLRB also plays a potential role in shaping the union's power. The impact of plant closures and subcontracting on the work force, for example, are mandatory bargaining issues. If the NLRB interprets its current legal precedent about displacement to also include displacement caused by the introduction of programmable automation, then the union's power to negotiate protective work rules is enhanced.

Finally, both employers and unions are sensitive to the sociopolitical climate. If public opinion supports notions of "job rights" and "employer responsibility" for displacement, then unions will draw on this support in negotiating with firms. Sociopolitical support for union initiatives will depend in large part on the impact of displacement on a given community. Communities have played, for instance, an active role in keeping some plants open.

In summary, the impact of unions on the diffusion of programmable automation depends on the cost to the union of its implementation and union sources of power. Likewise, the diffusion of programmable automation depends on the power of the employer (which is a function of the cost to the employer of changes in the work rules and the employer's sources of power). The cost to the employer of utilizing programmable automation can be treated as a standard investment decision. The rate of return is obviously reduced as unions are able to increase the cost of utilization (i. e., more expensive work rules). The ability of employers to keep the investment cost down is a function of their power sources. The sources of power are determined from the same set of economic, technological, organizational, legal, and sociopolitical parameters that determines the power of the union. Parameters that yield power to the union generally take power away from the employer, and conversely, Through negotiations over work rules, the parties will eventually sign a contract that generally reflects compromises by both, and which theoretically reflect the relative power of the parties.

The types of renegotiated work rules will also reflect the preferences of the parties. For example, unions and employers may be willing to trade regular wages and fringes for greater security provisions like retraining and relocation pay, since job security becomes a primary concern. The types of outcomes, for labor, therefore, are tied to relative bargaining power and preferences of the parties. One can imagine a wide variation in outcomes among unionized firms.

It seems reasonably clear that as the capabilities of programmable automation increase and as the price

per unit drops, there will be a substantial impact on unionized workers in selected occupations, industries, and localities. It would not be feasible for employers to retrain substantial portions of their work forces. Consequently, unions will attempt to bargain work rules that cushion the layoff experience of large numbers of workers. It also seems reasonably evident that as the diffusion of programmable automation progresses rapidly in nonunionized establishments, the longrun threat to unionized groups of losses in employment due to noncompetitive work rules will diminish the sources of power for unions. **As** such, it becomes less likely that unionized employers will agree to protective work rules.

Finally, let me briefly address the issue of union organizing activity of white-collar workers. First, the diffusion of programmable automation (especially in the form of computer-aided design and manufacturing) also threatens existing white-collar jobs. The desire for job security and due process are important factors in work group decisions to unionize. As noted in the section "Union Organizing Activity, " white-collar unionization has been increasing and remains a potential growth area for the union movement. Second, unions which can organize both blue- and white-collar workers, obviously increase their sources of bargaining power to negotiate protective work rules. Thus, in firms and industries with the greatest potential for white-collar displacement by programmable automation, the likelihood that white-collar work groups will unionize increases. One can note, for example, that white-collar workers at General Motors very recently have shown considerable interest in attaining UAW representation primarily, it appears, because of declining job security.

Data Analysis and Research Plan

Our knowledge of the relationship between the diffusion of programmable automation and labor-management relations is very limited. We simply have no adequate empirical information to make reliable judgments about the impact of unions on the diffusion of programmable automation, nor the impact of programmable automation on union-management relationships and worker displacement. In part this can be attributed to the modest and welcomed encroachment of programmable automation to date. However, if the type of projections of programmable automation utilization made by RIA are reasonably accurate (a threefold increase for 1985 over 1980, and twentyfold increase by 199o), the need to increase our knowledge on this subject is highly warranted.

I suggest that we examine existing evidence in light of the implicit models described above. The first step would be to formulate a set of tentative explicit empirical models derived from the **above** implicit modeling. Once the critical (and measurable) variables are identified and the models are written in appropriate functional form, we can begin efforts to obtain the necessary observations to test the models.

The information we seek covers: 1) the extent of utilization and how employers weigh the reaction of unions and / or workers in making investment decisions; 2) the negotiation experience (i.e., the changes in work rules); 3) the parameters of the sources of power for employers and unions; and 4) the impact on the work force (e.g., numbers of workers retrained, relocated, or laid off, etc.) Toward this end we need the cooperation of employers and unions. Unfortunately it is not clear at this point how much cooperation we will receive. The second step, therefore, calls for a limited exploratory effort to test the waters. In testing the waters, we can make a judgment of the likelihood of successfully gathering the necessary data. Furthermore, we will learn: 1) what data on the variables in the tentative explicit models can be collected, and 2) what additional parameters should be considered in our hypothesis testing.

If the second step indicates that further data collection is feasible, then as a third step we need to identify the users of programmable automation; and ideally, potential users. Given that in 1980 there were about 5,ooo robots installed, we have a fairly large population of programmable automation applications. RIA is probably the best source of information on users and potential users in manufacturing. After identifying the population of users and potential users, we can then begin the process of selecting a representative sample. A small population of users, however, would allow us to examine the entire population.

Finally, once the data have been collected, the explicit equations can be estimated. Only at that point should inferences be drawn, projections made, and policy scenarios evaluated.

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