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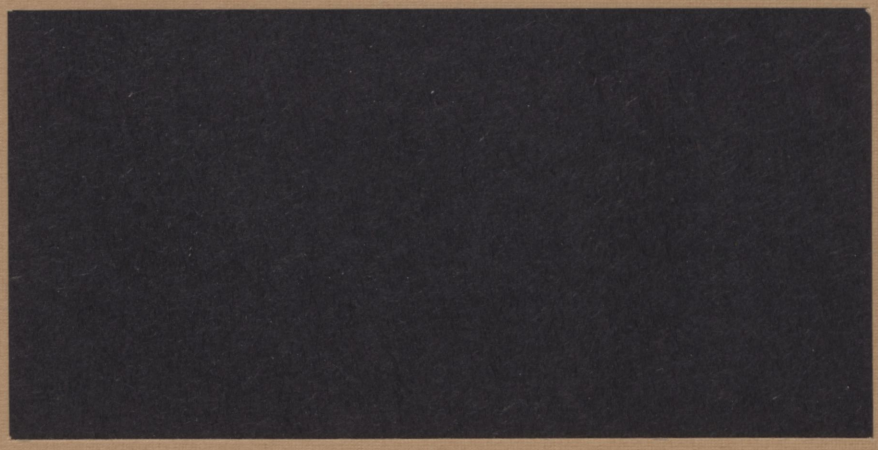

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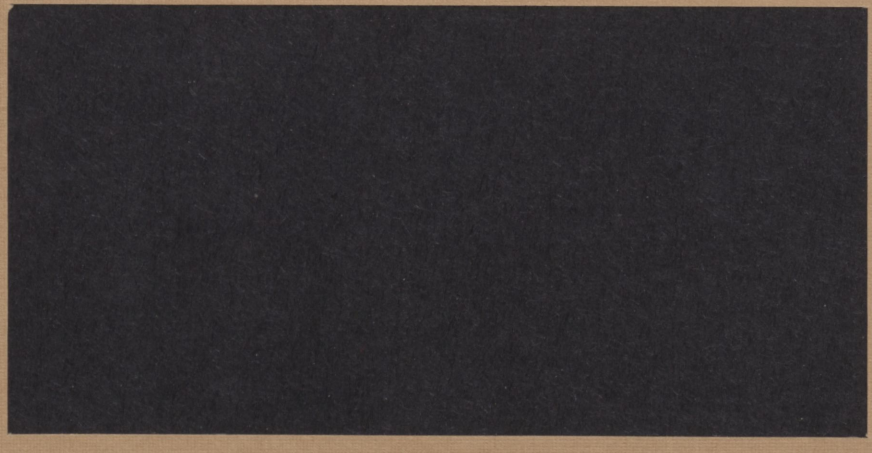

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MICROELECTRONICS AND THE MACROECONOMIC OUTLOOK

Two Papers fro the OECD Working Party on
Information, Computer and Communications Policy

by

Paul A. David*

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Discussion Paper No. 1

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Information, Computer and Communications Policy

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Paul A. David

The two closely related papers collected here are based on presentations made by the author to the 2nd Special Session of the O.E.C.D. Directorate for Science, Technology and Industry's Working Party on Information, Computer and Communications Policy, convened on 19-21 October 1981, at Chateau de la Muette, Paris, France.

The first paper is the Summary prepared by the author as Rapporteur General for the Conference. The second paper discusses the Analytical Review Based on the Reports of National Commissions, prepared by P. Stoneman, N. Blattner and O. Pastre, and presented to Session A of the Conference. Both papers are scheduled for publication in Spring 1982.

The opinions expressed and the arguments employed in these papers are the responsibility of the author and do not necessarily represent those of O.E.C.D., or the Center for Economic Policy Research at Stanford University.

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ANALYTICAL SUMMARY AND PERSPECTIVES ON INFORMATION TECHNOLOGIES, PRODUCTIVITY, EMPLOYMENT, AND WORKING CONDITIONS

by

Professor Paul A. David, Stanford University (U.S.A.)

1. Microelectronics and the Transformation of Information Technologies

Within just the past decade developments in semiconductor technology, leading to programmable microcircuits known as microprocessors, have opened before us prospects for the rapid evolution of the means of handling a great variety of tasks that involve the reception, manipulation and transmission of information. From an economic vantage point the crucial innovation realized by the microelectronic technology based on the microprocessor is simply the capacity to collect, generate and diffuse tremendous quantities of information at minimal cost. But the implications are profound. Rather than having merely "localized" significance for one or another branch of production or communications technology, the predictable impact of the implied expansion of the entire range of computer applications will be global in its dimensions.[1] In any context that currently makes use of some information processing devices--whether these be electric, electronic, mechanical, pneumatic, or hydraulic--microprocessors can be introduced. In many contexts the substitution is already economically advantageous. This accounts for the breadth of the immediately foreseeable range of the applications of microelectronic technology (MET, hereinafter), which presently extends from consumer goods like watches, through electronic games, wordprocessing equipment and other office machines, to the automation and control of entire industrial processes and transportation activities.

The impact of MET is being augmented by the convergence around it of other technological advances which extend the sphere of effective microcomputing applications, and are themselves accelerated by the potential that surrounds MET. The confluence around microelectronics of many sophisticated technologies, such as lasers, printing and display technologies, telecommunications, optical fibres, robotics, computer software design, and so on, already is so noticeable that one can begin to grasp the import of the microelectronic revolution only by considering it as a fundamental transformation of information technologies broadly conceived.

Realization of the potentialities inherent in this transformation undoubtedly will have far-reaching effects upon the organization of societies and the quality of human life. In general, the effect of technological changes has been an increase in the productivities of the primary factors--labor, capital, and natural resources. Our reading of the broad record of historical experience since the First Industrial Revolution suggests that the resulting expansion of capacity to produce goods and services whose consumption satisfies human wants in the long run, does yield improvements in average economic welfare.

Of course, economic welfare is only one among many ingredients of human welfare, albeit an important one, and technological developments may impinge directly upon the other conditions affecting peoples' sense of wellbeing. In commenting upon the "Analytical Review" of National Commission Reports on Microelectronic Technology, prepared by Consultants Stoneman, Blattner and Pastre, Professor Heertje has drawn attention to the ways in which microelectronic technology may affect welfare, apart from its impact on productivity, labor time employed, and earnings. His point is

that because such matters as job satisfaction, interpersonal relations surrounding work and consumption activities, and environmental quality effect individual welfare immediately and directly, they will effect people's market behavior. One cannot lightly ignore them when seeking to foresee how any given technological innovation will effect the market-determined and market-evaluated components of economic welfare.

But, when it comes to matters such as physical health, or personal dignity and freedom, or the nature of personal relations, or even the quality of the environment, unhappily we have no consensus as to the net welfare effects of technological change--at least none comparable with the agreement that exists regarding its long-run contribution to economic welfare. It therefore remains a matter for concern that developments in MET which can enhance economic well-being by bringing within reach higher material standards, at the same time may permit and even encourage the destruction of other conditions deemed essential, if not to life itself, then to the achievement of human happiness. This, however, is not the occasion to dwell upon such matters. The worries that have been repeatedly expressed about the potentially corrosive effects of the "computer revolution" upon individual privacy, for example, must find their proper consideration outside the narrower ambit of the present discussion of the likely economic welfare consequences of recent advances in microelectronics. We shall have enough to cope with as it is.

Although there is a reasonably broad consensus that average economic welfare eventually will be enhanced as a result of technological progress in the application of microcomputers, the subject matter that occupied participants in the 2nd Special Session remains both problematic and contro-

versial. Even when it is clear that economic welfare is going to be raised on the average, one is obliged to confront the problems of forecasting, measuring, and evaluating the actual distribution of the putative net benefits. To analyze concretely these future distributional consequences poses formidable challenges to our understanding of the economic systems throughout which the effects of technological change undoubtedly will ramify. Most of those challenges will have to be left for future applied researchers to meet. The following brief review of the various dimensions in which distributive questions may become paramount, at best can serve to suggest the scope and the complexity of key economic issues that are likely to surround the application of MET in the coming decades. At very least it can offer a framework in which to place a number of specific problems that commanded the main attention of participants in the ICCP Working Party's 2nd Special Session.

2. Distributional Aspects of the Impact on Economic Welfare

To begin with, the introduction of MET will alter the absolute and relative demands for the various inputs used in a wide array of production processes. Inasmuch as there is no reason to suppose those inputs all are available in infinitely elastic supply, we may therefore expect that the previously established constellation of relative prices, assets values, and rates of factor remuneration, will be disturbed. Some of these disturbances will be only transient, but in the longer run too there will be suppliers of some specific productive services who benefit by the change in prices, whereas others will have lost income or wealth. The induced redistribution of income and wealth among owners of productive assets may have

secondary repercussions, but, even leaving these to one side, the predictable effect of altered factor productivities in conjunction with disturbances in the structure of factor prices will be some changes in the relative prices and qualities of the goods and services available for final demand.

This latter effect on prices in the end-product markets will have differential consequences for the economic welfare of consumers who differ in their preferences between specific consumption goods, and between consumption now or in the future. Further, where commodities or factors of production are traded across national borders, the differential incidence of the economic welfare effects stemming from the alteration of available technology almost surely will become a matter of international concerns; not only the global distribution of economic welfare, but also the distribution of national power may be affected.

Within any given economy, the increment in "real income" represented by a gain in total factor productivity may be distributed many different ways. Under a regime of perfect competition it should go exclusively to consumers, via reductions of prices, or enhancements of product quality at stipulated prices. In the world in which we actually live, however, productivity gains may, at least for a while, go also to augment the real profits of stockholders, or to raise wage rates of workers whose skills or union qualifications (or both) render them a factor specific to the industry involved. The gains need not be taken in a pecuniary form. Quite possibly they may be devoted to furnishing managers with aesthetically more pleasing offices, or workers with cleaner, quieter, safer workplaces. It is understandable that even when agreements have been reached about the

past shape and division of the pie, the prospect of a new pie being baked, and the necessity of securing cooperation in baking it, will prompt new conflicts as to the form it should take or how it should be cut up. Although the advent of new technologies may precipitate such conflicts, their resolution will reflect the interplay of many forces and should not be viewed as being determined simply by technological imperatives.

This is the very essence of the issues in regard to "working conditions," which naturally occupied a prominent place among "the socio-economic dimensions of microelectronic supported robot systems," discussed in Section B. Every technology is compatible with some range of alternative forms of work organization or sets of working conditions. With some technologies, however, high costs are imposed--in losses of productivity or product quality, or increases in risk of serious injury to workers and damage to equipment--for departures from a narrowly defined pattern of work organization. Since prevailing levels of real factor incomes may thus be predicated upon adherence to a particular mode of organization of production facilities under the existing technology, the advent of a new technology that offers alternatives to established patterns of work organization without requiring the sacrifice of productivity, creates a potential for the redistribution of economic welfare--among the workers, owners, and managers of a particular industry, and consumers at large.

And even this has not exhausted the list of potential long-term consequences. Technological developments not only lead to changes in the details of production organization within factories and offices, but they alter the structure of industrial specialization, and the size distribution of firms. The latter, in turn, may bring about alterations in modes of

market behavior with respect to pricing, quality, investment in new capacity and, to close the circle, the allocation of resources to further technological innovation.

We must further be prepared to discover that as a consequence of the technological transformations implied by the application of MET, concepts and familiar statistical categories--themselves adapted to a previous technological regime, but still employed in monitoring and assessing the performance of the economy--have in significant respects become obsolete. Eventually, therefore, informed public policy-making will require renewed efforts at conceptualization and measurement of the long term economic welfare effects with whose distribution we have here been concerned. The presentation made by M. Mayer to Session C addresses this general issue, in the specific context of the development of a system of "satellite" statistical accounts to monitor growth and performance in the computer sector.

So far I have reviewed the possibilities of long-run benefits and costs being unevenly distributed within societies and among nations, even though the net effects of the transformation wrought by MET may turn out to be beneficial for the "representative" individual involved. This analytical construction, however, is a rather artificial one. It ignores a second group of problems that appear as soon as one considers the likelihood that the gains and losses of economic welfare may be distributed quite differently over time. The transition to an eventual situation of greater economic welfare may well entail passage through a phase, indeed for some individuals a prolonged phase, of technologically induced deprivation.

Here we come to the main preoccupation of Session A of these proceedings: the employment impacts of MET, and the spectre of job displacement

and "disemployment" resulting in "technological unemployment." Technological unemployment presents a problem in which the two classes of distributive issues I have thus far distinguished are both present. Some particular group of individuals within the society, namely the former occupants of jobs "displaced" in industries where labor productivity has been raised by new technology, are forced to bear immediate welfare costs; whereas others, and perhaps the initially displaced workers as well, are to subsequently reap the benefits in the form of reduced product prices and/or enhanced product quality. The practical and intellectual difficulties of arriving at a proper social resolution of just this sort of distributional conflict, involving a balancing of transient but nevertheless immediate and concentrated losses on the one side, against more permanent but remote and dispersed benefits on the other, accounts in large measure for the enduring place which the problem of technological unemployment occupies in debates over economic policy.

Moreover, unlike the issues concerned with the distribution of long run benefits and losses, the question of transitional unemployment can be more easily approached in a rough-and-ready way, by gauging the initial impacts of productivity increases on the growth of labor demands, and comparing these with the prospects for the growth of labor supply in the same short-run. This is precisely the kind of exercise which was carried out for the "Analytical Review" based on the National Commissions' Reports, and presented for discussion in Session A. An approximate assessment of the seriousness of the problem at this level does not turn on general equilibrium niceties: it does not require detailed knowledge of the factor-saving biases of various microelectronic applications, of input substitution

possibilities in other branches of production, of the elasticities of supply of productive factors, and of the price and income elasticities of demand for particular goods produced with (and without) the aid of microelectronics. The possibility of proceeding without immediately descending into such economic esoterica might be enough to explain the attention that has been focused throughout this 2nd Special Session upon the probable short-run labor market impacts of the impending technological revolution. Yet there is reason to look also to current macroeconomic conditions, and the retarded growth of international markets, for a more complete understanding of the present concerns that have been so much in evidence regarding the vexed question of technological unemployment. I shall try to develop this observation more fully in a moment.

A fourth discernable area of concern in the proceedings of the 2nd Special Session may equally be subsumed under the general heading of distributional issues that involve questions of timing. How far removed in time is that eventual equilibrium state in which the potentialities for long-run benefit will be realized? How rapidly may we expect to converge towards it? And will the transitional difficulties be greater or less if the speed of convergence is greater? This is, of course, to state only one side of the matter. The translation of new technological possibilities into actual product or process innovations is neither autonomous nor inevitable. Nor will the diffusion of innovations proceed automatically at some pre-determined speed. The interaction of technological innovations with the economic environment into which they are introduced generates feedback effects that exert a measure of control over both invention and diffusion processes.

This endogeneity of the rate and direction of innovation and of the speed and limiting extent of diffusion give rise once again to important distributional effects, over which we may hope to be able to exercise some influence. These may be seen to involve the distribution of (presumed) benefits between the members of present and future generations. The past and current generations have surely borne investment costs in creating the new technological possibilities based on microelectronics. Yet, the current and possibly also future generations may have to wait a while before reaping the full advantages. If the prospect is one of an extended painful transition, or simply long delays before we arrive at the promised state of affairs in which MET will be fully exploited, then a positive economic welfare evaluation of the whole course of development is certain only within the terms of a welfare calculus with perversely discounts the present in favor of future generations.

In the course of foregoing analytical overview, I have identified four problem areas that commanded particular attention from the participants in the several sessions of this conference. Although some of these problems may have been scheduled to be addressed specifically in one session rather than in another, their importance is such that they almost inevitably emerged as recurring themes, permeating the discussion as a whole. Baldly stated, they are:

- o the problem of incomplete labor market adjustments to technological change, and concerns about the appearance of technological unemployment under conditions of weakened growth in aggregate demand;

- o the problem of distributional conflict over the way in which the potential of MET for transforming working conditions is to be exploited;

- o the problem of the feedback effects of short-run economic, social and political conditions, which will affect and may retard the pace--or even limit the extent--of future applications of MET;

- o the problem of monitoring fundamental alterations in economic structures with outmoded and internationally incomparable statistical systems, and the significance for both private- and public-sector decision-making of overcoming information gaps about "the information revolution."

Rather than undertake a comprehensive summary and synthesis of all the findings brought forward, and the diverse views expressed with regard to each of these problem areas, in the remarks that follow I offer a more personal perspective on them in the light of some of the presentations and the discussions which ensued. I shall try to show that although they are distinguishable for analytical purposes, there also are important linkages between these problem areas which should be considered in the formulation of public policies.

3. Labor Market Adjustment Problems and the Macroeconomic Environment

Why should there now be such widespread concern over the possibility that technological progress in general, and particularly innovations based on applications of microprocessors, may lead to economic hardships for significant segments of the population in the industrialized countries? It seems clear to me that it is the recent deterioration of the macroeconomic environment that has fostered the tendency, both in the popular consciousness and in the economic press, to couple the subject of microelectronics with worries about intensified international competition and threats of technological unemployment. There are few indications of an impending discontinuity in the rate of introduction of new information technologies, or of their bias towards labor-savings becoming more pronounced, which might

otherwise account for this conjunction.

In the United States some twenty years ago, similar forebodings surfaced concerning the impending "computer revolution", and these fears formed the background for the inquiry undertaken by the National Commission on Technology, Automation and Economic Progress.[2] In Europe during the late 1950's and early 1960's, however, unlike the situation existing in America, there was little talk of "automation" causing unemployment. Bertil Olsson, then Director General of the Swedish National Labor Market Board, explained the contrast in the following way:[3]

> In the industrial countries of Europe, where in many places the development [of automation] has proceeded almost as far as in the United States, high employment and a demand for manpower have existed, so that in comparison with the industrial districts of the United States, unemployment has been very small. In other countries of Europe, where unemployment caused by technology can be found, the unemployment figures are comparatively high for other reasons. The unemployment due to technological advances vanishes in the higher aggregate figures of unemployment. People in Europe, therefore, do not speak of anyone as being unemployed as a direct result of automation.

Among western European economists of the time there was a diposition to dismiss the phenomenon which Americans called "structural unemployment" as merely an illusion. This derived from the faith that a combination of enlightened social policies regarding income distribution and reliable management of aggragate demand offered the means of ensuring "full employment." To quote again from Olsson's 1963 essay:[4]

> If, in a community where there is unemployment, a worker is discharged from his job owing to automation and then cannot find work, he is unemployed, not because of automation, but because he is living in a community which has not succeeded in securing employment for all of its citizens....To create and maintain full employment is an economic problem, not a technical one....To distribute the result of production to all groups in the community and to do so in such a way that a high demand is maintained is an economic-political problem which must be solved by political means. Countries which do not solve these problems will also be unable to solve the problems of technological change.

The orthodoxy of the 1960's held there to be no pathologies of the functioning of labor markets which could not successfully be treated with systemic therapy, in the form of macroeconomic policies designed to procure full resource utilization. This represented an aspect of the broader post-Keynesian creed that then held sway among economists in the West: the so-called "neoclassical synthesis." According to the latter effort at a superficial reconciliation of two fundamentally divergent analytical perspectives, the microeconomic allocation details could safely be entrusted to commodity and factor markets to perform efficiently and with reasonable dispatch, whereas government intervention was required at the macroeconomic level--using monetary and fiscal instruments to guide the economy to its full employment path and keep it there. One may contrast this post-Keynesian orthodoxy with the new consensus reflected in the "Analytical Review" based on the various national commission reports on the impact of microelectronic technology: neither the consultants, nor the discussants of the report presented to Session A, were at all sanguine about the efficacy of relying upon demand management measures to minimize the hardships caused by job displacements and labor market disequilibria. Consultants Stoneman, Blattner and Pastre foresaw no serious imbalance arising between aggregate labor supply and aggregate labor demand as a consequence of MET, but they expressed worry nonetheless about structural unemployment persisting due to difficulties of the supply-side adjustment to an altered set of labor-skill requirements.

This view is in the nature of a forecast, rather than a diagnosis of existing complaints. No convincing evidence has yet been found to support the notion that the upward drift of unemployment rates in the OECD coun-

tries over the course of the 1970's was a structural condition attributable to rapid diffusion of new technologies, let alone to the diffusion of information technologies specifically. The causes of the still more recent deterioration of the macroeconomic picture are generally understood to lie in other quarters. Restrictive money policies pursued by the authorities in the major industrial countries, in an effort to combat inflationary pressures generated by domestic money supply expansions or exchange rate depreciations, have contributed to raising real short-term rates of interest, while slowing the growth of international liquidity. Combined with a retreat from domestic fiscal policies formerly dedicated to placing ceilings on unemployment, and with persisting uncertainties as to the future course of inflation, high short-term interest rates have made it less and less attractive for the private sector to undertake long-term investment commitments of the sort required for major capital improvements. Stagnation of world trade has rendered it more and more difficult for exports to take up the slack left by the curtailed growth of domestic investment within the industrial countries as a group. The remaining cushion therefore has been government dis-saving, itself a cause of fears about inflation and the object of some budget-cutting experiments on the part of fiscally conservative governments who find themselves beset by recession-induced deficits.

3.1 Technological Unemployment and the Macroeconomic Environment:

Within such a national and international macroeconomic setting as this, it is not surprising that the prospect of a continuing stream of labor-saving technological changes based on microelectronic applications should begin to take on an altered, and generally less benign appearance.

Adverse aggregate demand conditions may interfere seriously with the operation of those so-called "compensation effects" which, otherwise, would mitigate the impact of technologically-driven job displacement. Two points may be briefly noted in this connection. First, as I have already remarked in discussing the "Analytical Review" presented in Session A, firms that find themselves constrained by demand are more apt to behave like monopolists than like competitors in regard to the use they make of labor-saving technological innovations. When it becomes technically feasible to rationalize their operations by eliminating fixed- and quasi-fixed employment among nonproduction workers, they are more inclined to pocket the cost savings rather than lowering prices and expanding production worker employment.

Second, although for any given open economy it is likely that the expansion of exports would permit compensating increases in the volume of production and employment to follow in the wake of labor-saving technological innovations, when a number of international trade partners find themselves facing a slowly growing or stagnant world market, only some will be able to enjoy this form of compensation effect. In his concluding remarks, Mr. Evans of the TUAC delegation re-emphasized the fact that while many OECD governments have adopted a strategy of attempting to increase their share of export markets, this is not a strategy which is likely to be feasible for the OECD areas as a whole in view of the negligible growth of world trade. In the same vein, Professor Krupp suggested that structural unemployment problems may have become more serious in West Germany during the past decade as a consequence of the reduced capacity of that country's export sector to reabsorb displaced workers.

Adverse aggregate demand developments also may contribute to structural employment problems by exacerbating the difficulties of adjustment on the supply side of labor markets. One of the ways in which such adjustments can be affected is through induced investment in upgrading the skills of young labor market entrants, and in the retraining of more experienced workers whose skills have been rendered obsolete. There is quite widespread agreement that investment in human capital formation, through general education and subsequent vocational training, will be critically important in facilitating rapid deployment of technological innovation without major social dislocations. This appears to be particularly the case now in connection with the microelectronics field, where the training process necessary for maintaining workforce flexibility and keeping pace with new technical developments is becoming more formal, continuous and costly. The paper presented to Session B by Messrs. Carlsson and Selg of the Swedish Commission on Computers and Electronics identifies "the education system" as "the main bottleneck" to rapid development in the application of robotics and computer-assisted design and manufacturing (CAD/CAM). In Session A, statements were presented by Dr. Scheuten of the delegation from BIAC, and by Mr. Richie of the U.S. delegation, both of whom stressed the need to provide employees with new skills and to offer retraining to those displaced by technological innovations--as a means of reducing hardship and lessening resistance to change.

In view of the importance attached to the sort of vocational and professional training, and retraining that follows general education, it is certainly troubling to notice that a deteriorating macroeconomic environment is not likely to be any more conducive to private human capital forma-

tion activity of this sort than it will be to other, long-term investment undertakings. The major component in the costs of on-the-job training is the deferred production and foregone earnings. Although various government subsidy schemes have been tried, much of the costs of such investment is left to be financed by firms and/or workers from retained earnings. The depletion during recessions of private financial resources available for such purposes, and the clouded outlook for the recoupment of investment outlays through future employment, make it even less likely that structural readjustments on the supply side of labor markets will occur smoothly. Workers who have lost jobs find it especially difficult to qualify for the specific training programs that are best conducted within firms which can provide exposure to the most recent vintages of equipment and the most up-to-date work procedures.

3.2 Macroeconomic Implications of Capital-Saving Tendencies in MET:

The predominant concerns over the short-run macroeconomic outlook reflected themselves equally in Professor Krupp's discussion of some potentially adverse consequences of capital-saving features of the new, microelectronic technologies. In conventional neoclassical analyses which assume an economy remains on the full employment path, a reduction of the capital-output ratio due to technological innovation is depicted as tending (when the elasticity of substitution between capital and labor is less than unitary) to push up the real wage rate and labor's share in factor income, while temporarily accelerating the rate of growth of the capital stock implied by any constant net savings rate. This means that a greater capital-saving bias in technological change would permit full employment absorption of a labor force which, for other, say, demographic reasons, had begun to

grow more rapidly. Given an accelerated rate of growth of the labor force without such an accomodating shift of the technological bias towards capital-saving, wage rates would have to decline to induce a fall in the conventional capital-labor proportions. Alternatively, the savings rate would have to be raised--and the consumption rate lowered--to provide a faster capital stock growth rate required to match the faster pace at which the full employment labor force was growing.

Under neoclassical assumptions, then, capital-saving technological change is clearly a blessing. But the comments of Professor Krupp were directed not to the problem of what conditions would obtain along the new full employment growth path defined by the adoption of microelectronics. Rather, they addressed the altogether different question of whether full employment could be maintained by a closed economy if the incremental capital-output ratio was being lowered by successive technological innovations.

The answer to this question turns on the demand-side implications via the effects upon the level of investment, instead of the supply-side consequences of capital-saving changes brought about through MET. At present the evidence is less ample and less ambiguous than one would wish, even as to the suspicion that the overall effect of microelectronic innovations will be to lower the capital requirements per unit of additional output capacity in many branches of production. Carlsson and Selg's contribution to Session B observes that there is "no unique impact of CAD/CAM on the requirements of capital"; in some instances the replacement of conventional machine tools with numerically controlled (NC) tools has reduced investment requirements, but elsewhere they have been raised. Manufacturing cells with a product-oriented layout typically have higher fixed capital require-

ments and would entail larger production volume to be justified without other considerations. This implies higher incremental capital-output ratios at the old level of production, but possibly lower ones if production can be concentrated in larger-scale plants. The existence of other sources of input savings, however, holds open the possibility that the new, fixed capital-deepening techniques may be introduced without greatly increasing the volume of production runs; not only are there labor-savings, but important gains come in the form of reduced inventory requirements, since in the new manufacturing cell concept the machines wait for materials and large buffer stocks are no longer required to keep production flowing smoothly. The entailed reduction of the inventory-output ratio might then offset the opposite movement of the fixed capital-output ratio.

What the overall final outcome would be still remains unclear, as are the dynamic effects of the transition from old to new production methods. Demand may be boosted for a while by the surge in gross investment outlays required to implement a new manufacturing system, or a computerized warehousing system equipped with "smart shelves," even though the effect of the change will be to lower inventories per unit of production or sale--and so to eventually reduce investment requirements. On the other hand, it is quite conceivably that significant capital-savings may occur without requiring much new investment in tangible production facilities; software improvements may render existing computer-controlled production systems more efficient in their operation, for example. While investments in software development and personnel retraining would be needed to effectuate such "disembodied" technological innovations, the fact is that these investment programs are difficult to finance by borrowing and most typically

have to be paid for out of retained business earnings. This last point, also brought out by Carlsson and Selg's paper, carries the implication that planned gross investment in such programs will be exactly matched by planned gross business savings, and thus cannot be expected to do much to stimulate income growth from the demand side.

Too much of this is conjecture without adequate empirical foundations, and rather gloomy conjecture at that. Nevertheless, it surely should suggest that MET's capital-saving effects and their macroeconomic implications form a subject that will repay more systematic investigations.

4. The Issues of Job Quality and Work Organization

Two somewhat distinct but nevertheless interrelated issues may be identified in the disucssion of the possible impact of MET on working conditions and the organization of production processes. First there is what I would call the "job quality" issue. Present conerns with this subject seem to me to reflect nothing so much as the uncertainties that surround the future attributes of specific jobs in offices and plants where the nature of the production process and the physical environment may undergo a profound technological transformation.

One way to approach this subject is to draw an analogy with the issue of "consumer protection" and uncertainties regarding product quality, including "product safety." Job quality can be considered to be a dimension of the output of a multiproduct production activity organized within a firm--or more properly, a bundle of dimensions of the firm's product array. Some of the firm's outputs it designs for sale to its customers. The others--those described on the job quality dimensions of task variety or

repetitiveness, frequency of contact with co-workers or isolation, absence of stress-producing noise and vibrations, degree of control over work-pacing, and so forth--are "outputs" which the workers "consume" in varying quantities. The mix of outputs produced by a firm is not predetermined by technology; technological choices may be made in an effort to achieve organizational objectives such as cost minimization, subject to profit-maximizing decisions as to the volume and mix of outputs. The firm may adjust the attributes of each element in its line of marketed products, and the relative amounts produced, to suit the tastes of its customers. And it may also devote advertising and other costly efforts to attempts to adapt the tastes of its customers more closely to the pattern of its existing or emerging production advantages.

Essentially the same view of matters applies where the "customers" are the workers who consume job quality attributes, and the employing firm has the option of accomodating their tastes or seeking to persuade them to accept the sorts of jobs that it prefers to offer. There well may be room for cooperation between the two sides in selecting the complete output mix for the firm, as is the case where an enhancement of job quality through reduction of repetitiveness yields fewer work defects, lower costs of product quality control, and higher profits. But conflicts are bound to arise if creating more satisfactory working conditions entails higher costs of producing the outputs which are destined for the market, and workers resist paying for improved job quality through downward adjustments in their monetary compensation or fringe benefits.

Looked at from this angle, the job quality issue posed by the advent of microelectronics in the workplace is in large measure simply the generic

problem of product novelty. A job is a complex commodity whose characteristics may be difficult to comprehend and evaluate even after it has been experienced by a succession of workers; a host of new jobs fashioned in a rapidly evolving technological environment, holds out all the atractions and terrors of the unknown. In the multiplying proposals to facilitate serious consultation of workers in advance of the design of new working conditions, one may read a call for greater assurance that, as consumers of future job qualities, they will be informed and thus "protected." But the matter goes beyond this. The assertion of workers' "rights" to participate in this process, as exemplified by the statement of Miss Forward of the delegation from TUAC in Session A, appears to me to be tantamount to a claim to the exercise of a more meaningful degree of "consumer sovereignty" than would be afforded merely by choosing among the employment situations available at one establishment or another. Since rather intractable problems of jointness in production, and externalities arising from the interrelated aspects of work organization within a given physical facility, have rendered the "market for job qualities" notoriously imperfect, worker participation in the process of job quality design appears a much more effective way of influencing, and particularly of widening the range of available choices.

Beyond the understandable impulse to exercise control over the unknown, in the case of microelectronic-based industrial technologies such as computer-numerical control (CNC) of individual machines or groups of machines, there does exist the potential for greatly widening the range of choice between different types of work organization; the organizational options available with the introduction of CNC machines include the cen-

trally programmed and controlled, automated production line, at one extreme, and the decentralized, small batch production production operation in which CNC machines are programmed by skilled workers on the shop-floor, at the other extreme. The existence of these and still other, intermediate options associated with the development of the so-called "flexible manufacturing system" (FMS) was well brought out by Profesor Crossley's "Key Lecture on Robotics," and the discussion which followed in Session B. In the present inhospitable macroeconomic environment, however, the rationalization of production processes for the purpose of cutting costs may be the only objective that conerns firms introducing CNC machinery. In the pursuit of that goal to the exclusion of all others, there is a real danger that the potential flexibility of work organizations compatible with efficient use of microelectronic technologies will remain unexplored. Given the substantial elements of sunk costs in the design of production facilities, future options for work organizations--and the quality of jobs within them--may thereby be foreclosed for some time to come.

Informed customer participation in product development is quite commonplace nowadays in high technology industries, and some transfer of those constructive supplier-customer attitudes to the realm of management-worker negotiations over changes in working conditions does not seem too much to ask for. Without it, we face the distinct possibility that employers will spend resources trying to convince workers to put up with job attributes they do not like, while workers will adopt the defensive strategy of seeking only to protect their past "standard of consumption" in regard to job qualities--at the cost of rejecting the potential welfare gains from an enlargement of the sphere of choice, not to mention the possibilities of

greater productivity.

There is a second issue, this one concerned with work organization, which is less direct but more strategic in its bearing upon the distribution of potential welfare gains from technological progress. The organization of work within factories and offices obviously affects the quality of the jobs experienced by individual workers. But we should appreciate that it also may affect workers' self-perceptions and behaviors as members of collective action groups. It will be recognized that the resolution of future distributional conflicts between employees and employers over wages and working conditions will reflect the strength of trade union organization, among other factors. Those likely future conflicts will therefore become referred to the present, in the form of disputes involving aspects of proposed changes in current work organization--whenever the latter are perceived to have some bearing upon the union's future ability to mobilize labor for collective bargaining or other action.

Concerns expressed over the isolation of workers glued to remote computer terminals with visual display units (VDU's), in offices or in their homes, may well be grounded on consideration of the psychological effects (and the eye-strain) imposed upon the individuals involved. But it also may reflect attention to the greater costs of organizing, and of building trade union solidarity among men and women who have only limited personal associations with their co-workers. In the same vein, fears concerning the possible effect of the spread of microelectronics in polarizing the workforce into disparate economic and social groupings, with highly educated technicians and professional personnel at one pole and unskilled manual laborers at the other--such as were expressed by the statement of

the Norwegian delegation in Session A--take on a strategic complexion when one stops to consider what such polarization would mean for the political and economic strength of existing trade union organizations. "Deskilling" represents a loss of economic rents and a threat to the livelihood of the skilled; it has another, and no less painful meaning for the organizations that draw much of their membership strength from such workers. But individual and organizational interests in the consequences of MET are not inevitably allied. Decentralization of production processes can enhance job quality by increasing the range of work skills, the variety of individual worker's tasks, and the sense of personal involvement in the performance of autonomous work groups. Autonomous work groups which are not afforded facilities for social contact and meetings at the work site, however, could be used to fragment the workforce and undermine trade union organization--with potentially dire consequences for the future economic welfare of individual workers.

The recent deterioration of the macroeconomic outlook is intensifying fears that trade unions, engulfed in a rising tide of unemployment, will find coming collective bargaining sessions a painful test of strength. Hence, more and more attention is likely to be paid to preserving unions' organizational bases in the existing structure of production processes. One cost of the business community's acquiesence in the use of unemployed workers as cannon-fodder by the generals of the "war against inflation" is likely to be the further encouragement among trade union leaders, as well as in the rank and file, of the paranoid style--the distrusting, conservative reaction against all changes in work organizations proposed as accompaniments to the introduction of microelectronic technologies.

5. Feedback Effects on the Diffusion of Microelectronics

The rate of technological diffusion is not determined outside the economic environment in which adopting firms must operate. Rather, the diffusion process itself, no less than the eventual extent to which new products and processes supplant old ones, is subject to endogenous controls exercised by conditions in the markets for goods and services. Thus, as I pointed out in discussing the "Analytical Review" presented to Session A, the emergence of structural disequilibrium conditions in labor markets--as is widely foreseen in the form of redundancies among unskilled and semi-skilled workers in the youngest and oldest age brackets, coupled with shortages of computer engineers, electronics technicians, programmers, and the like--would have the reflexive effect of tending to slow down the technological diffusion process that was generating those excess supplies and demands.

While we should derive some comfort from the fact that the diffusion of MET will not be an autonomous process, but will instead be subject to "feedback" regulation and control, there is equally some ground for concern. Once the diffusion process starts within a macroeconomic environment which exacerbates the difficulties and short-run dislocations that normally attend technological change, the institutionalized reactions and economic policy responses that may be induced could seriously limit the long-run benefits of continuing innovation. Induced political intervention aimed at regulating the introduction of labor-displacing technologies would constitute a non-market feedback loop controlling the short-run unemployment situation; but there is reason to suspect that such regulatory mechanisms would prove less easily reversible in their operation than the automatic

feedback mechanisms--driven by current and anticipated market conditions.

One of the most striking aspects of the 2nd Special Session has been the emerging appreciation of this problem. Session A began by addressing the question of whether or not microelectronics was to be held culpable for the rise in unemployment rates experienced in the major industrial countries during the past decade. The "Analytical Review," prepared by Stoneman, Blattner and Pastre on the basis of the national commission reports, brought it a "scots' verdict" of "not proven." Having accepted that conclusion, the participants in Session A soon turned to consider whether the potentially beneficial developments flowing from MET might not in fact become the victim, rather than being a cause, of the deteriorating macroeconomic environment. There was a remarkable consensus on this matter, a consensus which I think is evident in the printed record despite the different ways in which the concern has been expressed, and the more apparent disagreements as to what ought to be done about it.

I shall elaborate a bit further, in order to document this observation. On the one side it has been suggested that perhaps too much attention is now being given to the potential problems and dislocations which will attend the introduction of microelectronic technologies into the workplace. Dr. Scheuten, of the delegation from BIAC, emphasized the opportunities that productivity advances would offer in meeting the challenge of raising material standards of living while protecting the environment and making work experiences more satisfying. His remarks noted the danger that such opportunities for improving welfare may be lost from view; that adequate encouragement of inherently risky innovation therefore would not be forthcoming. The statement made in the same session by Mr. Richie, of the

American delegation suggested that if the private sector were only given proper tax incentives and freedom from regulatory restraint, it would be equal to the task of successfully managing the introduction of microelectronic technology in the coming years. It is implied that a widely held perception of MET as the bearer of labor market dislocations, and of greater social costs of coping with the injurious consequences of change, would tend to weaken the case for providing special incentives for investments in technological innovation--just at a time when restrictive monetary and fiscal policies have made the provision of such incentives all the more essential.

On the other side, the view has been expressed that there is a real need for frank acknowledgement of the disruptions and hardships that may accompany the introduction of MET, and a commitment by private groups and public agencies to seek ways to ameliorate the problems of structural readjustment. Were this not to be forthcoming, and were the policies of governments perceived as simply promoting the diffusion of new technologies which displaced workers and devalued their skills, there would most likely be a reaction that would in the end inhibit even beneficial change. Mr. Evans, of the delegation from TUAC, in his remarks prepared for the closing session, emphasized that the recent determination of governments in the industrial countries to tolerate high and rising unemployment--in order to break the cycle of inflationary expectations and price-wage increases--has done nothing to dissuade trade unions from adopting a "job defense" strategy of resistance to all changes in work rules. In such a situation, as Professor Braun's comments on the papers in Session B suggests, special provisions for worker-retraining within the enterprise, or assistance in

relocation, will become especially important in averting opposition to change.

A further significant point has been brought out by Miss Forward's remarks in Session A on the subject of worker-consultation: little would be gained if workers came to perceive, and distrust "consultation" as a formal exercise undertaken by plant management for the purpose of facilitating pre-determined alterations in work rules, rather than as an effort to achieve true participation of employees in the redesign of the work organization. A more optimistic corollary of this proposition may be suggested: effective collaboration and consultation with worker's representatives in the development and introduction of new production processes would seem to require rather higher levels of technical expertise on the workers' side of the bargaining table than has generally been called for until now.

Further, to promote the more rapid deployment of new processes and modes of work organization that reflect workers' job quality preferences may require some signification adaptations on the part of labor organizations as well as on the part of management. Company-level labor organization, for example, has proved particularly successful in facilitating the consultative redesign of work organization and new methods in Japan and some of the Nordic countries. Whether such a restructuring of trade union representation is the only adaptation possible, or whether we shall see the use of specialized consultants engaged to make technology assessment studies on behalf of industrial union organizations, is a matter on which it seems too early to render a judgement. It is certainly an open possibility that in the area of collaborative design and assessment of microelectronic

technologies from the worker's vantage point, a new field of technological expertise will emerge. If such turns out to be the case, this will have been one of many instances in which new and more interesting jobs were created by the microelectronic revolution.

6. Conclusion and Recomendations to Improve the State of Information

There is an unavoidable if unpleasant message in the foregoing interpretive account. The present deterioration of the domestic and international environment affecting many of the industrial countries is not the fault of MET. But it has begun to cast a pall over the once-bright prospects for an early enjoyment of the contributions that may be made to human welfare through the widespread application of a vastly more powerful information technology. As many of the problems identified here remain in an incipient stage, there is still time for action. And as some of those impending difficulties are aggravated, if not caused by ignorance and uncertainty as to what the future holds in store, effective remedial action can take the form of providing better information than we now possess about the dimensions of the information revolution. This may not suffice, but it suggests a useful role for O.E.C.D.

Let me turn then to the question of specific directions for future work. At least three main programs of information-gathering and analysis, in my view, would meet with approval and encouragement among the Delegations that have participated in the 2nd Special Session. First, there is the program of developing statistical accounting systems in the information field. This needs to be approached in a way that will promote maximum international comparability. The paper presented to Session C by M. Mayer

not only called attention to the work of I.N.S.E.E. on the development of the "satellite statistical account" concept, it also provides a specific model whose adoption should be considered by various statistical agencies in Member countries.

I cannot stress too much the importance of seizing the opportunity to anticipate developments in the microelectronics field by putting in place even a temporary statistical structure that would facilitate the gathering and comparison of data. To be sure, subsequent refinements in such accounting systems will have to be undertaken in close collaboration with scientific and technical personnel in the information field, and with commercial enterprises, so as to anticipate the likely direction of the technology's evolution. This will go some way to avoiding the rapid obsolescence of statistical measurement concepts, which otherwise tends to foster the notion that one should wait until things have "settled down" before trying to collect any systematic information. In order to maintain the necessary flexibility, further development of the "satellite accounts" approach should be undertaken--rather than attempting an ongoing revision of the central system of national accounts.

The second area in which O.E.C.D. can make significant contributions relates to the monitoring and reporting of specific technological developments in the microelectronics field. The present session has heard many requests for the sort of concrete information that would be pertinent to "choice of techniques" decisions by firms, or by labor organizations. Such information would prove relevant in a number of contexts. It may be of use in permitting potential adopters of MET innovations to survey rapidly the range of alternative production processes and work organizations of which

they should be apprised. It would contribute to allaying unwarranted fears of job-displacement, or of losses in investment goods orders, and would also serve to identify those areas in which severe labor market adjustment problems can be anticipated.

Further along the same line, it would seem to be very much in the interests of all concerned to have available to the potential adopters of new microelectronic-based production systems an evaluation of the conditions under which specific processes are most likely to prove commercially profitable. Such information would provide some guide to the future course of diffusion of specific innovations, and improve the ability of private and public agencies to anticipate change. But there is also a need for information about the contexts in which the introduction of particular innovations will occasion social costs not borne by the innovators, and thus warrant some public interventions; or, alternatively, social benefits not captured by those undertaking the innovation expense, and thus warrant the provision of public subsidies. Generalization about such matters is not possible. Only detailed studies can provide an adequate basis for public policy decisions regulating the introduction of a particular new technology or product. Yet the findings of such studies may be applicable to similar situations obtaining in many different Member countries of O.E.C.D.

Third, there is a need for parallel case studies of the longer term social and economic sequelae of the introduction of microelectronics, and other new technologies. Innovation represents a step into the unknown, and one should at least be prepared for the possibility of unanticipated consequences. The only way I know to undertake such preparation, and to height-

en responsiveness to early signs that unexpected outcomes are emerging, is through the medium of follow-up studies of instances of commercially successful and unsuccessful innovation. A few carefully designed studies of this kind, at very least, ought to be carried out in great detail. They should enlist the cooperation of all the parties involved in examining what transformations actually took place in the work organization, in the qualities of jobs within those organizations, and in the lives of the men and women who were caught up in the process of technological change.

FOOTNOTES

1 Cf., P.A. David, Technical Choice, Innovation and Economic Growth, Cambridge: Cambridge University Press, 1975, pp. 58-68, on the concept of "localized" technical change, contrasted with innovations which yield alterations in the "fundamental production function" which underlies available production processes at a given point in time.

2 Cf., National Commission on Technology, Automation and Economic Progress, Technology and the American Economy, Washington, D.C.: Government Printing Office, 1966.

3 B. Olsson, "Policy Implications of Technological Change in Western Europe," ch. 8 in G. G. Somers et al., eds., Adjusting to Technological Change, New York: Harper and Row, 1963, p. 192.

4 Olsson, op. cit., pp. 199-200.

INFORMATION TECHNOLOGIES, PRODUCTIVITY AND EMPLOYMENT: COMMENTS ON "THE ANALYTICAL REVIEW BASED ON NATIONAL REPORTS"

by

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Introduction and Accolade

Consultants Paul Stoneman, Niklaus Blattner, and Olivier Pastre are to be warmly congratulated on their splendid response to a difficult challenge. Faced with the task of synthesizing quickly the diverse collection of National Reports on the productivity and employment implications of microelectronics technology, they have provided this Session with a careful and judiciously balanced review of such fragmentary and often inconsistent pieces of empirical evidence as are on hand. To help us interpret the significance of the variegated straws now blowing in the wind, they have furnished a coherent framework within which the labor market impact of technological innovations may be analytically examined. This analytical framework is one that treats the "generic" aspects of technological change rather than directing attention to the distinctive characteristics of the revolution in information technologies being wrought by developments in microelectronics; it addresses questions that might equally be asked concerning the eventual productivity and employment implications of recent advances in recombinant genetics, or in fibre optics. Proceeding within this general framework, the Consultants' Report devotes its main emphasis to assessing the magnitude of the primary, labor-displacing effects of the productivity improvements associated with the diffusion of microelectronics innovations,

on the one hand, and to identifying and evaluating the strength of possible compensatory, employment-generating effects on the other hand.

The resulting synthesis reads the evidence as insufficient to convict the spread of microelectronic technology of responsibility for the recent rise of unemployment in western Europe and the U.S., or to justify projecting an atmosphere of crisis in which private individuals and public authorities should be anticipating large-scale job displacements, attended by grave economic and social repercussions. Instead, the Report argues for a general attitude of calm in monitoring current and future developments in the application of microelectronics; of skepticism when presented with prophesies of technological upheavals coming in a sudden, uncontrollable and catacylsmic wave, rather than through slow, continuous, and economically regulated changes of an incremental nature; of faith that the long-run consequences of the gradual microelectronic revolution most probably will be for the best; and, finally, of assurance that the appropriate response by public bodies to the appearance of "transitional" problems is to intervene where labor markets fail to smoothly reallocate resources, but otherwise not to seek to protect jobs by arresting the technological developments that impell such reallocations. Indeed, on the latter point, the Consultants' most definite tones are reserved for their assertions that international competition will deprive open economies of the freedom to choose to slow or halt the spread of microelectronics, so long as the preservation of domestic employment opportunities remains a major policy objective. The clear message is "export or die, and accept modernization or cease exporting."

Economists and Technological Unemployment--from Ricardo to the Report

As a fellow economist, I naturally find it reassuring that the Consultants' Report adopts the time-honored stance of our profession, which is to remain optimistic regarding the effects of technological change but to eschew becoming cavalier about the risks of technologically induced unemployment and other possible consequences prejudicial to general economic welfare. Economists' efforts to preserve this ambivalence can be traced back easily as far as the writings of Ricardo on the subject of technological unemployment.

Indeed, it is quite striking to observe how faithfully in both substance and tone the text of the Report before us recapitulates themes originally ennunciated more than 160 years ago, in the midst of the First Industrial Revolution. David Ricardo, it should be recalled, also was a long-run optimist regarding the possibilities for economic progress: he saw continued technological change (and the opening up of international trade along the lines of comparative advantage, of course) as avenues leading away from the dismal slough of the stationary state. Yet there was in Ricardo's writing a strong tension between long-run hopes for continuing technological improvements and worries about the more immediate consequences of such changes. It is this tension which has periodically mounted and abated, without ever being resolved in the economic literature.

As Mark Blaug has pointed out, the general preoccupation of Ricardo's analysis of economic processes was with long-run equilibrium outcomes, whereas his treatment of the impact of technological "improvements" upon wages, profits, and rents, concentrated largely upon the short-run.[1] Nowhere was this so striking as in the famous Chapter 31, "On Machinery,"

which Ricardo appended to the third edition of his Principles in 1821. This brief chapter managed to shock his readers and provoke a "furore of debate" among contemporary political economists,[2] by suggesting that the introduction of labor-saving machinery might be injurious to the workers, causing unemployment when real wages could not be forced downward. Ricardo introduced this heresy after restating his own prior orthodoxy--that

> an application of machinery to any branch of production, as should have the effect of saving labour, was a general good, accompanied only with that portion of inconvenience which in most cases attends the removal of capital and labor from one employment to another.[3]

Putting aside the frictional "inconveniences" as commonplace, the longer-run sanguine view was grounded upon the now classic "compensation effects" argument; improvements, in the form of mechanization of production, would lead to a reduction in commodity prices from which all customers would benefit, including the laboring classes. Even if productive capacity in one branch of industry grew faster than demand there, displaced workers would be reabsorbed in employment elsewhere.[4]

The particular difficulty whose recognition Ricardo felt himself obliged to announce in 1821 was one that could arise in the transition to a more machine-intensive technique of production. If output had to be diverted from consumption purposes to the production of capital goods, the supply of commodities for consumption as wage goods would fall--to the detriment of the laboring population. At least temporarily. Once the new machines came "on line", so to speak, the supply of wage goods gradually would be augmented, prices would fall, and labor could be reabsorbed into employment without there being a significant reduction in real wages. (Works, I, pp. 389-90.) Economists in the developed countries no longer

worry about precisely this form of transitional unemployment arising from technological progress.[5] But it is worthwhile noticing that the potential problem of "structural" unemployment, acknowledged in the present Report, is fundamentally a similar condition--one in which prolonged displacement of workers results from supply-side constraints rather than from an insufficiency of aggregate effective demand.

Looking at the likely developments of the supply and demand for labor during the coming decade, the Consultants have concluded that the spread of microelectronics will not exert a markedly adverse effect upon the balance between the aggregates. What worries them more is the prospect that the structure of skill demands, and the industrial structure itself, will most probably be altered so as to curtail job opportunities for young unskilled workers generally, for the older and least mobile members of the workforce attached to traditional branches of commodity production and trade, and for females seeking secretarial and clerical positions without higher educational or skill qualifications. (Cf. Report, pp. 59-60.) Redundancies may therefore persist among such groups, even though the want-ads continue to advertise vacancies for designers and engineers in microelectronics, computer programmers, and electronic office equipment sales and service representatives. One way to think about this is to see the problems as rooted in a lack of savings required to carry out the socially requisite human capital formation accompaniments to investment in hardware embodying the new technology. Such complementary human capital formation would initially furnish new workers, and re-equip old ones, with the skills sufficient to allow their absorption, or re-absorption, into productive employments at the formerly prevailing real wage level.

In a pure market economy the lack of savings for such purposes could arise because the private rate of return on the necessary investments in people was too low, or because imperfections in capital market institutions denied some people access to financing. Yet even where the political and institutional context would facilitate public educational and retraining investments, it is possible that the investment cost of retraining displaced older workers is so high, and the pay-off period so brief, that any positive social rate of discount would imply that retiring such workers at their former wage levels would be socially less wasteful than re-equipping them for private sector employments at those wages.

The public policy issue posed by this line of analysis then turns on the question of whether or not the present value of the stream of producer and consumer surpluses yielded by the new technology would be large enough to cover not only the direct investment costs, but also the present value of the incremental social outlays for worker retraining and/or premature "retirements." A positive answer, of course, is no guarantee that the society will opt actually to spend the productivity gains from microelectronics or other technological advances on "subsidies" for education, retraining and retirement.

Ricardo's long-run optimism only carried him so far as to contend that the labor-saving improvement eventually would generate enough additional income and savings to cause the re-employment of a workforce of the original size. The workers, therefore, would be hurt in the interim, and he had to grant

> That the opinion entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy. (Works, I, p. 392.)

It is fair to say that the Report at hand seeks to allay alarms on this score, not so much because they are empirically unjustified in the case of microelectronics as because the threat of reactive public policies grounded in such fears appears even more worrisome for open economies in today's climate of international competition. In this final respect too, the Consultants (Report, p. 80) have arrived at precisely the same point as Ricardo, who concluded that "the employment of machinery could never be safely discouraged in a State" (Works, I, p. 396), since to inhibit the use of more productive techniques, when one's foreign competitors did not, was likely to have an even more disasterous impact upon domestic employment.

To recognize that it would be economically more costly for a modern industrial society to seek to "protect jobs" by limiting the application of microelectronics, and that such policies are likely to be self-defeating, does not, to my mind, provide any warrant for minimizing the potential severity of the adjustment problems and conflicts that may surround the introduction of these new technologies. The greatest danger of overstating the magnitude of the factor market dislocations arises when it is perceived that social mechanisms for compensating damaged parties are non-existent or inadequate. Those who, rightly or wrongly, anticipate that they may sustain significant injury are then left to act unilaterally or in concert to preserve their immediate interests by blocking the impending changes. Most of modern economic analysis, which dwells fondly upon the operation of endogenous, market-channelled mechanisms of "compensation", seems to

encourage existing tendencies to gloss over the transitional difficulties that will befall some individuals, and to dwell instead upon the long-term benefits that accrue to society as a whole from the introduction of technological improvements. In a perverse way, it may thereby actually promote the worrisome perception that little will be done to prepare politically-directed, social machinery for the provision of compensatory assistance to the victims of change. This contributes to creating a climate in which the economist may well feel it is "more responsible" to risk erring on the side of over-sanguinity than to risk erring on the side of alarmism.

Compensation Effects and the Long-Run Employment Outlook

Without intending to impute any such conscious or unconscious motives to our team of Consultants, I wish to suggest that their Report has perhaps gone farther than might be useful in the direction of eschewing alarmism. As far as the long-run labor market prospects are concerned, the sanguinity of the Report appears to derive mainly from the appraisal of the so-called "compensating effects" as being collectively quite large in relation to the anticipated rate of job-displacement due to the diffusion of microelectronic innovations. There surely is ample room here for doubt, and at least two notes of skepticism and worry should be sounded. The first concerns what we presently do and do not know about the magnitudes of labor-savings and compensating effects at various levels between the individual establishment and the macro-economy. The second concerns the possibilities of serious disjunctions in the spatial or the temporal occurance of job-displacement and job-creation. I shall take these up briefly in turn.

There is much need for detailed engineering information about the

factor-saving and factor-using biases of microelectronic technologies in a variety of production contexts, but also about the ease with which various inputs may be substituted for one another--given the production technology that is in place. It is not sufficient to trust that because an innovation "will only be introduced (rationally) if the services it provides are cheaper than with the previous technology", as the Report (p. 3) observes, the tendency to use such services more intensively will substantially counteract the shrinkage in the demand for the productive inputs. Micro-engineering data at the process and department levels, as well as organizational design information for the establishment, is needed to tell us how much substitution response can occur when the relative efficiency-prices of some inputs are reduced. At best we may take the presumed existence of some intra-plant compensation effects as qualifying the impression conveyed by partial engineering analyses; but the direction of the qualification is not always unambiguous or reassuring. Engineering data which show the number of welders displaced from automobile production lines by automated spot- and arc-welding machines, do not also indicate that (cheaper) welding may also have been substituted for other assembly techniques--with further labor-displacing consequences.

When the analysis moves to the level of the firm, the effects of a labor-saving technological innovation upon unit costs, and the effect of the cost change upon prices and the volume of sales, must be considered in order to guage how large an offsetting increase in labor demands will materialize. Under conditions of perfect competition one is justified in supposing that all unit cost savings are translated into price reductions. When firms hold market power, however, the form of the cost savings

becomes a crucial issue determining the existence or non-existence of a tendency towards the compensating expansion of production. The reduction of marginal costs would occasion some expansion in the volume of production of a firm which had monopoly power, just as it would in the case of the perfectly competitive firm. But a reduction in fixed costs would not have the same effect, as it would leave the profit-maximizing volume of output unaltered and simply raise the monopolist's profit level. Inasmuch as we do not live in a world in which perfect competition is the norm, it becomes important to know more than we now do about the way the introduction of microelectronics will impinge upon the fixed and variable elements of cost in the various branches of production. Casual empiricism is less than reassuring on this point: it suggests that since computerization of record-keeping and control functions (i.e., inventory management), as well as in a range of clerical support services, is likely to have maximum impact in displacing non-production workers who represent elements of quasi-fixed costs for manufacturing establishments, the existence of compensating effects through the expansion of production in those plants will depend critically upon the strength of the competition to which manufacturing firms are exposed.

This brings me to the second point. The existence of international competition provides some grounds for reassurance that cost savings in all forms may lead to compensating increases in output and labor demands, or will at least stave off losses in market share and domestic employment opportunities. But to seize upon this argument is to grasp a two-edged sword: the logic of the analysis of compensation effects offers nothing to guarantee that all the employment generating repercussions of the introduc-

tion of a labor-saving innovation will compensate the region or nation in which the job displacements have occured. Design engineers and machinists may be put to work in Cincinnati, Ohio, building dedicated industrial robot systems that will displace workers (at some subsequent date) from the paint-spraying departments of automobile plants in the environs of Detroit, Michigan. But we soon would begin to think differently about this, were Ohio and Michigan two different countries--or even in two very distinct regions of the United States. Actually, in contrast to the American pattern of specialization in robot production, major automobile makers in West Germany and Japan have been extensively engaged in building robots for their own use. Yet, watching Toyota and Volkswagen increase their hold upon both the automobile and the numerically controlled machine tool markets cannot be much compensation for workers in Britain's industrial midlands. And what of the effects upon the Turkish labor market, not to mention the balance of payments, if Volkswagen-built robots displace many immigrant workers from semi-skilled automobile assembly jobs in West Germany? It may seem awkward, and unnecessarily divisive on this occasion to name names and places. But these or similar realities eventually will have to be faced; by simply being discreet, the Report cannot help us to begin to think constructively about the international dimensions of the coming microelectronic revolution.

The international repercussions may indeed prove to be more far-reaching than has hitherto been suspected, making it all the more important to discard the implicit closed-economy premise upon which has been based much of the traditional economic literature concerning compensation effects. International competition in information-intensive activities may

alter substantially the situation that has long prevailed in those sectors of many economies which enjoyed a large measure of protection by virtue of the "nontradeable" nature of the services they produced. Non-tradeability may turn out to be too evanescent a quality to be relied upon. As developments in satellite communications, microwave transmission, and, eventually in applications of fibre optics, further reduce the already low marginal costs of transporting information as a commodity, there will be pressures (already felt) to remove legal, institutional and other barriers--including those of national language differences--to trans-national trade in information-intensive services. This may have profound effects, bring about a restructuring of those parts of the service industries which operate in financial markets, in shipping and insurance brokerage, and in commodity markets where economies of scale and specialization in the acquisition and processing of information are very important. Thus, the service sectors of many national economies, which have in the past decades absorbed in increasing share of domestic employment, increasingly centered in information-based occupations, may now have reached a state in which profound dislocations can occur as a result of their exposure to international competition. To be sure, there will be gains from trade. But in any single economy the long-run employment prospects may not be so assured.

Life in the Short-run: Transitional Problems and the Macroeconomic Outlook

As for the short-run--in which, as Keynes reminded us, life such as it is must be lived--the Report candidly admits that labor markets should not be expected to function smoothly in matching currently available labor supplies to the altered pattern of labor demands implied by the introduction of microelectronic technologies. Hence, even if the long-run employ-

ment picture were unclouded by prospects of a net displacement of workers, transitional dislocations could turn out to be serious enough to call for new public measures in addition to a strengthening of existing "safety-net" provisions. The magnitude of such difficulties, and of the consequent burden they will place on the existing unemployment, social insurance and welfare apparatus, will be greater or smaller depending upon two sets of factors. The first are those affecting the rate of initial job-displacement, which is to say, the rate of reduction of unit labor input requirements at the plant or establishment level brought about by technological innovations, and the pace at which such innovations are introduced. The second set of factors are those which will influence the functioning of labor markets, either by altering the price and quantity signals, and the costs of such information to the workers and firms, or by affecting the speed with which the participants can respond to signals of excess supply or excess demand.

Under the heading of the first of these considerations, it may be worth starting with the observation that the extent of plant level job-displacement connected with productivity-enhancing technological change is almost certainly greater than one would be led to surmise from empirical studies carried out at the industry level, or still higher levels of aggregation. Over any era in which demand for an industry's products has been expanding, jobs lost through the modernization of existing production facilities are likely to be offset in some part, if not entirely compensated for, by jobs created through the opening of new plants in different locations. The magnitude of the required labor market reallocations is therefore generally under-represented by statistical studies

which find weak or non-existent job-displacement effects of technological change at the industry, sector, or domestic-economy levels--some of which are uncritically cited in the present Report.

This is not mere theoretical conjecture. A special study, motivated by the concern that technological displacement of labor at the plant or establishment level might be more extensive than that appearing at the industry level, was undertaken in the 1960's by the U.S. Bureau of Labor Statistics for the National Commission on Technology, Automation and Economic Progress.[6] The evidence gathered from establishments in 17 4-digit SIC industries over the period 1947-1961 reveals that labor productivity advance displaces production worker manhours at the same level, i.e., the establishment, at which it occurs; that if there are immediate compensation effects these are at best only partial, and less likely to occur within the same establishment when aggregate demand is weak. In fact, it was found that during an episode of adverse macroeconomic conditions, the negative association between employment growth and productivity advances at the establishment level was more clearly evident, and that the plant "disemployment" rate was higher within those industries in which the negative employment-productivity covariation was most marked. In sum, the long-run growth of employment and productivity which is observed at the level of industries and entire economies may warrant faith that technological advance conveys benefits to the working population as a whole, and may even support the Consultant's contention that the application of microelectronics is unlikely to produce an aggregate deficiency of employment opportunities in the 1980's; but it should not be misread as indicating that the technolgically-induced displacement of workers is only a

minor problem for modern industrial economies.

Perhaps a sounder basis for discounting the possibility of temporally bunched, massive dislocations in labor markets is to be found among the factors affecting the rate of diffusion of the new, microelectronic technology. The Report (pp. 63ff.) quite properly observes that the historical experience of the diffusion of process and product innovations suggests that progress towards widespread adoption will occur far more slowly, and gradually than some journalistic previews of "the Microelectronics Revolution" would lead one to expect. Moreover, it details many specific conditions--ranging from inadequacies of the telecommunications infrastructure, to the resistent attitudes of management personnel--which have been identified as impediments to the introduction of microprocessors by firms during the 1970's.

In this connection, a point deserving of more notice than it has received is simply that the rate of technological diffusion is not determined outside the economic environment in which adopting firms must operate. Rather, the diffusion process itself, no less than the eventual extent to which new products and processes supplant old ones, is subject to endogenous controls exerted by conditions in the markets for goods and factors of production. Thus, the conditions of structural disequilibrium which the Consultants fear may emerge in labor markets--redundancies among skilled and semiskilled workers, coupled with shortages of computer programmers, electronic engineers, and the like--would operate reflexively to slow down the diffusion process that was generating those excess supplies and demands. The existence of this feedback loop provides an important stabilizing effect for the system as a whole. If rapid adoptions of a

labor-displacing innovation by many firms were to leave in their wake severe unemployment and social dislocation, it is unlikely that this damaging course of development would proceed unchecked except in very small, open economies; elsewhere, the labor market effects on relative wage rates and therefore on the inducement to save labor, and possibly also the adverse income effects of the loss of employment upon the demand for investment in new capacity, would militate against continued diffusion of the innovation. Induced political action to regulate the introduction of labor-displacing technologies would constitute a non-market feedback loop, but one that many suspect would prove less easily reversible in its operation.

All stabilizing processes, whether they work through market or through non-market channels, must impose some costs upon the economy. In this instance technological changes which enhance factor productivity will be introduced more slowly. Further, if innovative activity is encouraged and financed by prospects of gains realized ultimately through commercially profitable applications, then slowing the anticipated rate of diffusion would also adversely effect the pace at which new technological opportunities will become available for adoption. The feedback loop through endogenously controlled diffusion cannot prevent unemployment and labor market disequilibria arising from rapid technological advances, but it will moderate them and transmute these costs of change into economic costs of other sorts, which are likely to be distributed rather differently among the members of society.

I must turn at last to the second set of considerations that bear upon the short-run outlook, those influencing the ability of factor markets

to cope with transitional disequilibria. Here it may be remarked that the new information technologies which are the subject of discussion may have a beneficial effect if they are more widely applied to the problems of monitoring local labor market developments, pooling data on the existence of vacancies (and redundancies) in employment categories with specified skill qualifications, and computer-matching individual workers to jobs over larger areas than is now feasible. A network of computer-assisted labor exchanges would make periods of "frictional unemployment" shorter. Better information would tend to reduce the dispersion of rates of return on investment in retraining, or in labor migration, or in both. It seems obvious that public sector investment in this area should be re-examined in the light of these emerging tecnological opportunities.

On the opposite side however, one must avoid basing unwarranted optimism upon the large scale reallocations of labor and capital that have been achieved in the market economies of the West during the post-Second World War boom. For the macroeconomic picture is much gloomier presently than anything which industrialized nations as a group have known during the past twenty-five years. When employment demand contracts to levels that imply substantial margins of labor redundancy, the savings of workers who are on short-time or unemployment assistance begin to be depleted. But it is largely from such savings that workers must (internally) finance general job-training, or retraining to permit relocation to occupations and geographical locales where excess labor supply conditions do not prevail. Weak growth of demand and dwindling profit margins also sap the resources from which firms may (internally) finance specific job-training programs, and new technology-embodying investments that help maintain their competi-

tive position. Indeed, it appears that because necessary software development and the training of workers in computer-aided design and manufacturing processes are difficult to finance externally, investment in microelectronics equipment itself may be more cyclically sensitive than might be supposed by those who consider only its productivity-enhancing effects.

Demand-constrained firms behave more like monopolists, and asset-constrained workers are less likely to shift occupations and locations in response to deterioration in their earnings opportunities. It is easy to see, then, how adverse demand side developments in the macroeconomy--arising from deflationary monetary and fiscal policies--will compound structural, supply-side causes of unemployment. What otherwise would be comparatively brief episodes of technological displacement and temporary unemployment in the lives of individual workers, are more likely to degenerate into prolonged bouts of joblessness, dissaving, and growing personal and social disorientation.

In the present climate of universally retarded economic growth, intensified international competition, and rising unemployment rates in western Europe and the United States, it must be conceded that the mounting concern expressed by workers and union leaders over the detrimental short-run employment consequences of accelerated technological progress is a reaction "not founded on prejudice and error"--to recall the famous phrase used by David Ricardo.

FOOTNOTES

1 Mark Blaug, Economic Theory in Retrospect, Third Edition, Cambridge: Cambridge University Press, 1978, pp. 111-12.

2 Cf. Maxine Berg, The Machinery Question and the Making of Political Economy, 1815-1848, Cambridge: Cambridge University Press, 1980, p. 44.

3 The Works and Correspondence of David Ricardo, vol. I: on The Principles of Political Economy and Taxation (edited by P. Sraffa), Cambridge: Cambridge University Press, 1951, p. 386. All page references in the text hereafter are to the Sraffa edition.

4 Cf., Works, I, p. 387. Ricardo seems to have had in mind an expansion of labor demand in branches producing commodities (other than food) for which the price elasticity of demand was quite high. But the key explanatory passage was ambiguous enough to have referred equally to shifts in demand due to the income effects of the price reductions in the branch where mechanization was occurring.

5 But cf., J. R. Hicks, A Theory of Economic History, Oxford: Oxford University Press, 1969, pp. 151-54, 168-71, J. R. Hicks, "A Neo-Austrian Growth Theory," Economic Journal, Vol. 80, No. 318 (June 1970), pp. 257-281; E. F. Beach, "Hicks on Ricardo on Machinery," Economic Journal, Vol. 81, No. 324 (December 1971), pp. 916-22.

6 National Commission on Technology, Automation and Economic Progress, The Employment Impact of Technological Change, (Appendix Vol. II of Technology and the American Economy), Washington, D.C.: Government Printing Office, February 1966, pp. II-9 through II-25.

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