SIMPLE ANALYTICS OF THE EMPLOYMENT IMPACT OF TECHNOLOGICAL CHANGE

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In the debate concerning the economic consequences of technological change much has been written about the possibility of job loss. Relatively few studies have used an explicit framework of micro- and macro-economic analysis to examine this topic, however. Assertions about the employment outcome of the process of technical change tend to involve pessimistic generalisations from particular cases or a resort to optimistic predictions based on elegant but unrealistic neoclassical analysis. The present paper is designed to use simple tools of micro- and macro-economic theory to illustrate a variety of factors which may impinge upon this complex question and to show the circumstances in which technologically-induced unemployment may arise.

Keywords: technological change, employment, micro- and macro-economic theory.

INTRODUCTION

There is widespread agreement about the enormous benefits conferred upon mankind by the process of technological change. Such change has often brought problems of adjustment and adaptation in its wake, however, and — as the Luddite riots illustrate — has not always been greeted with unsullied joy. In particular, concerns have often been expressed about the possibility of technological unemployment. Recent claims that the economy faces a new wave of technical innovations unparallelled in the speed and breadth of their diffusion has led many observers to raise once again the spectre of technology-induced job displacement.

The issue is of crucial interest to all economic agents, as technological change is both propitious and perilous. Thus it is critically important to employers who face high wage costs and low rates of growth of productivity; to unions who welcome the fruits of productivity growth but fear its employment consequences; to consumers whose potential gains in the quality and cost of living may be offset by jobs lost or deskilled; and to governments which frame industrial strategies for international competitiveness, economic growth, and full employment without inflation. Not unexpectedly, commissions and committees of enquiry have produced volumes of testimony reflecting a considerable range of opinion.[1]

Economists have not as yet made a particularly distinguished contribution to the debate about the employment impact of technological change, which appears to have three more or less identifiable strands.[2] First is the pessimistic position of those who maintain that the current wave of technological innovations is quite unlike anything ever observed before: more far-reaching in the range of its potential disemployment effects and so rapid as to cause severe dislocation. A popular exemplar of the pace and severity of microelectronic technological change is the fate of the European watch industry at the hands of the Japanese. Generalisation from such examples naturally leads to the frightening prospects of widespread job loss and eventual mass unemployment. A second position stems from the optimistic observation that technological change has proceeded throughout history and that, despite its radically productivity-enhancing effects, widespread unemployment has not resulted. This view tends to emphasise the potential output-increasing effects of productivity improvement, and the ability of market forces to adapt to change and gravitate toward full employment equilibrium. The popular exemplar for this position is the banking industry, in which the employment-eroding impact of the new technology has been offset by the many new services that have also accompanied technological change.

A third position is clearly intermediate but occupied by observers whose views are presented with varying degrees of clarity and expressed with varying degrees of conviction. Some find the two extreme positions unacceptable but are frankly agnostic. Others emphasize the complexity of the issue, allude to some of the variety of factors that render the employment outcome of technological change uncertain, and stress the impossibility of accurate prediction. Thus the Myers and ASTEC reports suggest that the outcome will depend *inter alia* upon the nature of the technological change (its labour — or capital — saving bias, for example), the economic climate in which it is introduced, the presence of associated organisational change, and the employment potential of scale and multiplier effects. Both reports underline the perils of forecasting and of "notional job reduction"[3] estimates:

> Simplification is likely to be misleading; it is not acceptable, for example, to define the employment effect by the number of extra workers who would be needed to achieve, without the new technology, the outputs now achieved with its aid, because this approach fails to recognise that some of these goods and services would not have been provided without the use of the new technology.[4]

The reports acknowledge the possible disemployment effects of labour-saving technological change, and raise the possibility of "jobless growth" or "not-firing-but-not-hiring". While both point out the human costs of adapting to the social and economic dislocations accompanying technological change, neither sounds the tocsin for massive technological unemployment.

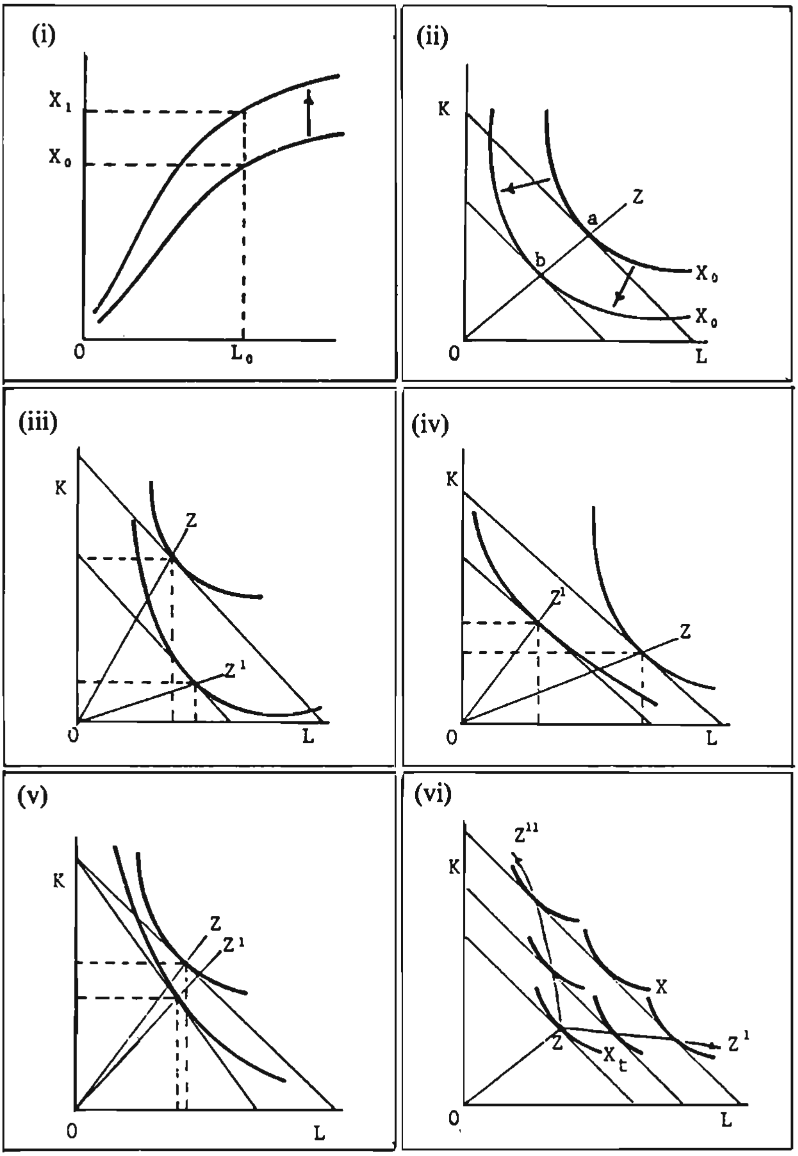
It is our contention that the position represented by the Myers and ASTEC reports (a position based, it must be said, upon a broad consideration of relevant literature) is admirably equivocal but lamentably vague. To those of us not expert in this area but also not innocent of economics, the complexity of the issue seems plausible and an agnostic conclusion sensible. But one is left to wonder whether the economic arguments might not be more firmly grounded, the propositions more convincingly demonstrated.[5] It is the purpose of this paper to bring to bear some more formal, but simple, micro- and macro-economic theory on the issue at hand.

The micro-theoretic framework of section 2 first addresses some terminological preliminaries: the concepts of neutral, factor-using, -saving, and -augmenting technological change, embodiment, etc. The diagrammatic representation of some basic production theory also illustrates the contributions of changes in the technical relations of production, and of changes in relative factor prices, to the employment impact of technological change. And it clearly portrays the implications of scale effects and the pitfalls of notional disemployment estimates. The more macro approach of section 3 provides a broader view of the issue of technological unemployment and labour market adjustment, and of relevant policy potential and constraints. Concluding comments are contained in section 4.

A MICRO PERSPECTIVE

The simple framework of production theory allows us first to dispense with some terminological preliminaries. As for technological change itself we concentrate upon changes in the technical relations of production. In the broadest sense this could include productivity-enhancing changes not only in the capital-labour mix but also in the relative proportions of other inputs in the production process such as raw materials, energy, and organisational design.[6] In economic terms the result of such changes is shown in Figure 1(i) by the upward shift of the production function, showing an increase in potential output $(X_1\text{-}X_0)$ from the given factor input L_0. Equivalently the effect may be illustrated by means of isoquants, as in Figure 1(ii). Technological change permits the output X_0 to be produced with lesser amounts of the two factor inputs, L and K. The isoquants corresponding to X_0 is accordingly relocated closer to the origin. Note also in Figure 1(ii) that with no change in the factor price ratio (shown by the parallel isocost

FIGURE 1
Neutrality, Bias, Price and Scale Effects in Technological Change



lines) the post-change equilibrium at *b* is on the some isocline *OZ* as the former equilibrium at *a*: the technological change has involved no change in relative input proportions and is therefore deemed "neutral".

In Figure 1(iii), by contrast, not only the position but also the shape of the isoquant has changed. The new input mix shown by the isocline OZ^1 involves proportionately more labour *(L)* and less capital *(K)*. Technological change of this nature is "capital-saving". Figure 1(iv) shows "labour-saving" technological change which has resulted in the use of more capital and less labour (compare OZ^1 to *OZ*) to produce the same output.[7] Technological change may therefore enhance or augment the productivity of a particular factor of production and, importantly, it may be embodied in particular machines or people. To use the well-worn phrase, technical progress does not fall like manna from heaven to augment all the economy's factors or production equally. Rather, it may be particularly embodied, for example, in the latest machinery and equipment; recent graduates of institutes of technology will embody the most up-to-date knowledge of their subject; and new or remodelled firms will reflect the latest organisational design and administrative practices. In reality, therefore, the vintage of factor inputs is an important consideration.

In reality also, changes in relative input proportions generally — and, therefore, in the employment impact of technological change specifically — are likely to be affected not only by the technical relations of production but also by changes in relative factor prices. Thus, not only will marginal rates of technical substitution change; so, too, will the slope of the isocost line. The history of the increasing technical power and rapidly-decreasing cost of the microchip vividly illustrates this point. In Figure 1(v) the assumption of constant factor price ratios in Figures 1(ii), (iii) and (iv) is relaxed. The new equilibrium input mix is now determined by a (capital-saving) change in the technical relations of production combined with a (labour cost-increasing) change in relative factor prices.[8] In principle, therefore, the positive impact on employment of a factor may be offset by an increase in its relative price.

Next, so-called scale effects are frequently invoked to demonstrate that the absolute employment loss for a factor of production as a result of technological change may be recouped by consequent expansion in the scale of production of the firm or economy in question. Thus a recent commentator on the Myers report maintains:

> If the increased productivity resulting from the technological change is reflected in lower prices, demand for the product of the firm will increase. Demand will also be stimulated by higher real incomes. Technological change can then lead to a higher output than otherwise would have been

produced, with consequently higher employment. This is the scale effect and it is always positive.[9]

As Figure 1(vi) shows, however, an increase in the scale of output need **not** lead to such an increase in employment. Let X represent the isoquant corresponding to a given output level under the original technology and X_l the isoquant for the same output level after technological change. Smaller absolute quantities of both K and L are now used but from equilibrium at Z an increase in the scale of operations along the expansion path ZZ^{II} involves not increased, but decreased employment of L.

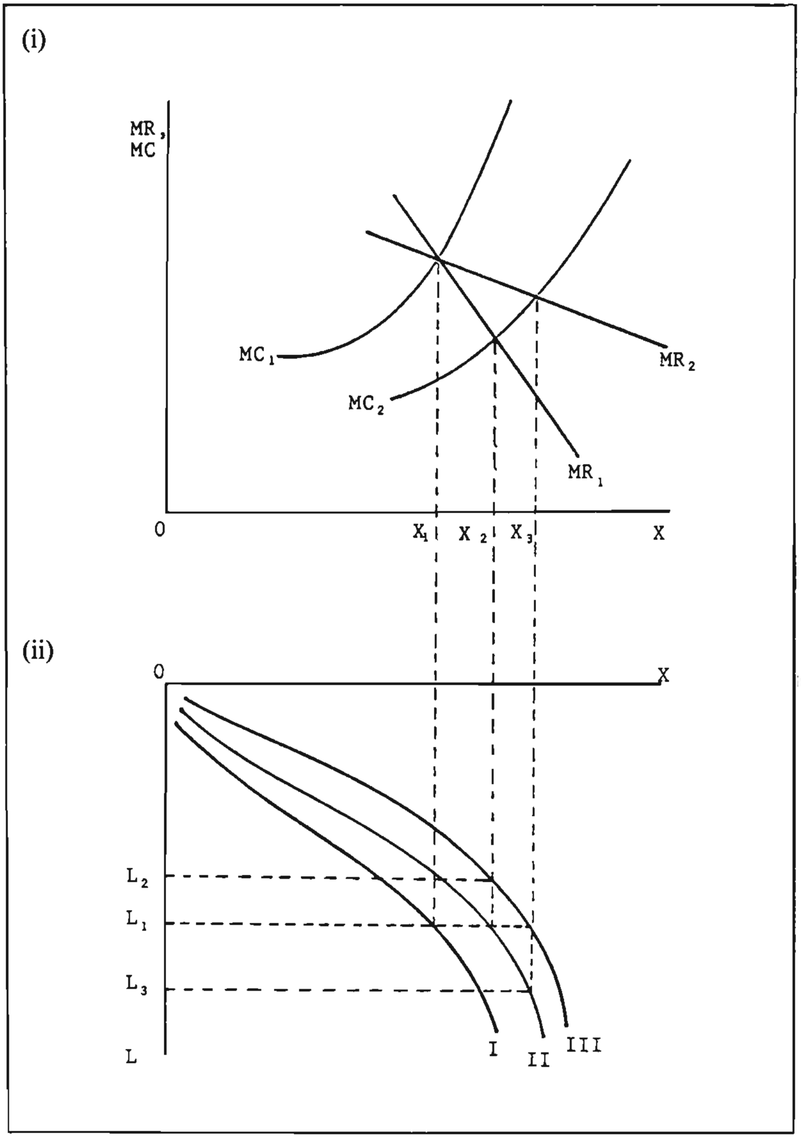
The question of scale effect is a complex one, however, and requires further elaboration. It depends *inter alia* upon the magnitude of the cost reduction accompanying technological change, the elasticity of demand for the product in question, and the change in the technical relations of production. In panel (i) of Figure 2, for example, a firm's marginal cost functions are shown before (MC_1) and after (MC_2) technological change. The cost-reducing effects of the change lead (with marginal revenue function MR_1) to a new output equilibrium at X_2. In panel (ii) of the diagram the initial output X_1 is produced by the initial production function I with L_1 units of labour.

After the cost-reducing change in technology the higher output X_2 is achieved via production function II with the same amount of labour as was required formerly. The increased scale of output from X_1 to X_2 has prevented any loss of employment.[10] With a more favourable elasticity of demand, moreover, manifested in the more elastic marginal revenue function MR_2, the scale of output would be greater still (at X_3) and, via production function II, would require L_3 units of labour. This represents an increase in employment from the initial (pre-technological change) position. Note, however, that with production function III even the favourable demand elasticity presented by MR_2 is only sufficient, at output X_3, to maintain the initial employment level L_1.[11]

It is apparent, therefore, that the employment effects of technological change are, indeed, highly complex and that scale effects may, or may not, be sufficient to offset potential employment loss. The outcome may depend on a host of factors, of which three have been illustrated here: the change in the technical relations of production, the magnitude of the cost-reducing effect, and the elasticity of product demand. For such reasons the prediction of the employment consequences of changes in technology is a hazardous business. Moreover, the presence of scale effects makes even *ex post* analysis complicated. This is highlighted by the admonitions of the Myers and ASTEC reports about the folly of notional job-loss estimates which calculate the difference between (i) employment with

FIGURE 2

Demand Elasticity, Cost Reduction, and Productivity Components of the Scale Effect



the new technology and a higher output level and (ii) the employment at that higher output level if the old technology had still been in use. The difficulty with such an estimate is, of course, that the increased scale of output attendant upon technological change might never have occurred in the absence of that change.

The concept may be illustrated with the aid of Figure 3. The pre-change equilibrium is shown at *a* on isoquant *X* with input proportions given by the isocline *OZ*. Labour-saving technological change now changes the shape and position of the isoquant so that the same output is represented by isoquant X_t; and equilibrium at *b* involves a higher capital-labour ratio. Suppose now that scale effects lead to higher output of X_t^1 and a new equilibrium at *c*. The "notional job loss" is thus the horizontal distance between points *c* and *d* where the latter represents the equilibrium if the same new level of output X^1 were produced using the former technology. Three other relevant measures of the employment effect may also be seen in Figure 3. The first is simply the difference in employment levels between the pre-and post-technological change equilibria, *a* and *c*, respectively. The second involves examination of the employment levels at points *a* and *b*, where the technologies are compared at the same output level. Alternatively one might ask what would be the employment level with the new technology if the pre-change cost outlay were maintained. This involves comparison of the initial equilibrium *a* with point *e*, which is on the same isocost line but on the post-change isocline OZ^1.

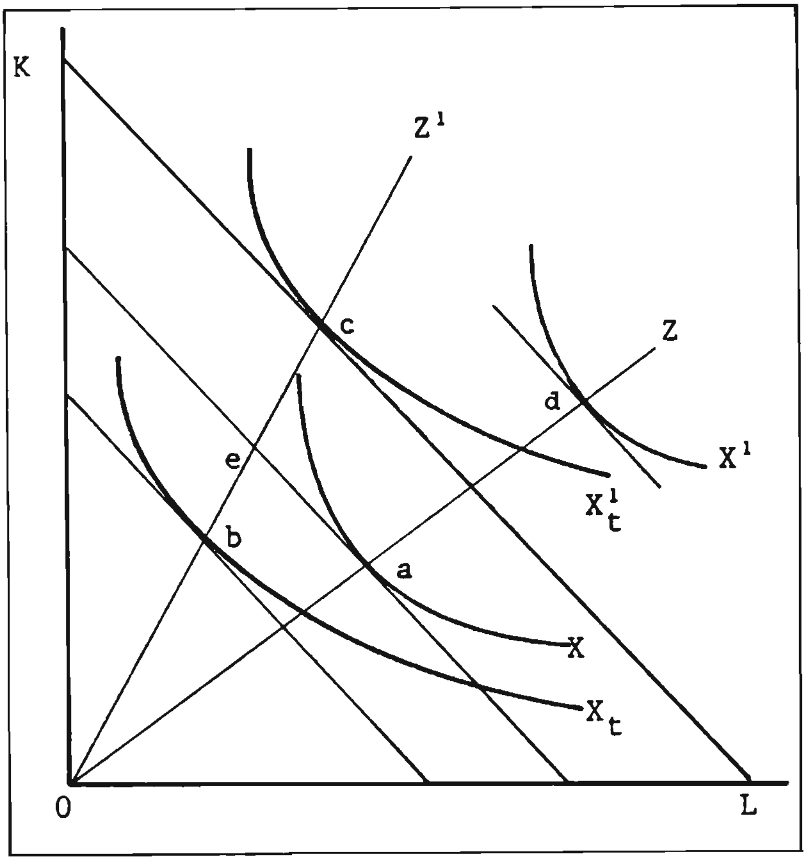
In practice the concern about employment effects is not only that labour may be replaced by other factors of production in some processes, nor even that productivity improvements may render even greatly expanded output levels attainable by a vastly decreased work force. Additional concern stems from the potential distributional aspects of the employment effect: across industries, regions, and skill levels. These features of technological unemployment are considered within the more macro-economic perspective of the following section.

MACRO-ECONOMIC CONSIDERATIONS

An important aspect of technological change is that it adds to the difficulties of pursuing such macro-economic objectives as growth, full employment, price stability, distributional equity, and balance of payments viability. This is because the institutional and structural elements of stagflation may affect and be affected by the process of technological change in such a way as to constrain even further the efficiency of conventional aggregate demand policies.[12] This section concentrates specifically on three ways in which technological change may cause maladjustment in the labour market and impose

FIGURE 3

Estimates of Notional Job Loss



constraints on policy. The first has to do with the special effects on the components of aggregate demand that might arise from the sharpness and rapidity of technological change. The second is concerned with the short-run frictional adjustment problems associated with adaptation to change in a world of immobility and inflexibility. The third is associated with fundamental mismatching of the aggregate pattern of skill requirements and the economy's pattern of skill endowment.

On the first question while there is no overwhelming evidence of a marked acceleration in the pace of technological change in the recent past, some commentators nevertheless contend that the impact of microelectronic innovations will be swifter and stronger than for any previous changes in technology. The very rapidity of such changes makes them hard to anticipate and plan for, so that at least short-term labour market dislocation may be expected. But if in addition the changes are strongly labour-saving there may be doubts about the ability of scale effects to make good the prospective employment loss. What are the potential sources of aggregate demand to fill the gap?

As far as private investment demand is concerned one might expect a sanguine view of increased profitability to lead to increased investment embodying the new technology and to increaed expenditure on related inputs. But the flow of investment could be dammed by union action or modified by entrepreneurs' concerns for the social consequences of disemployment. Expectations are clearly important to consumption decisions, also. Sharp increases in the income of those enjoying the fruits of productivity may be regarded as transitory. Consumption will then fail to respond fully to higher income levels. Furthermore, if people's perception of the future technological environment is that it is more risky or uncertain — more job changes, a higher probability of unemployment — they will alter their intertemporal pattern of spending and saving to meet possible future income losses. Current consumption may therefore be curtailed and expenditure multipliers reduced accordingly. As far as government expenditure in concerned, finally the prospect depends very much on the susceptibility of the unemployment to demand stimulation and on the anticipated inflationary consequences. Broad monetary and/or fiscal measures of demand stimulation appear unlikely to have salutary effects on the employment of persons displaced by technological change, as the remainder of this section maintains. Unless the cost and price-reducing effects of productivity improvement are a sufficient offset, the effect of such government demand stimulus on technological unemployment will be inflationary.

The second major employment effect of technological change derives from its impact on the structure of the economy via shifts in patterns of demand and supply of goods and factors. Adjustment to such shocks requires knowledge and mobility on the part of factors of production that may, in reality, be diminished by a variety of economic and social factors. The redeployment of labour across occupations, industries and regions may be further impeded if, in addition, institutional forces such as maintenance of wage relativities inhibit the factor price flexibility conducive to adjustment. Thus rapid rates of technological change may be accompanied by high rates of short-run frictional unemployment that is unresponsive to conventional macro policy.[13]

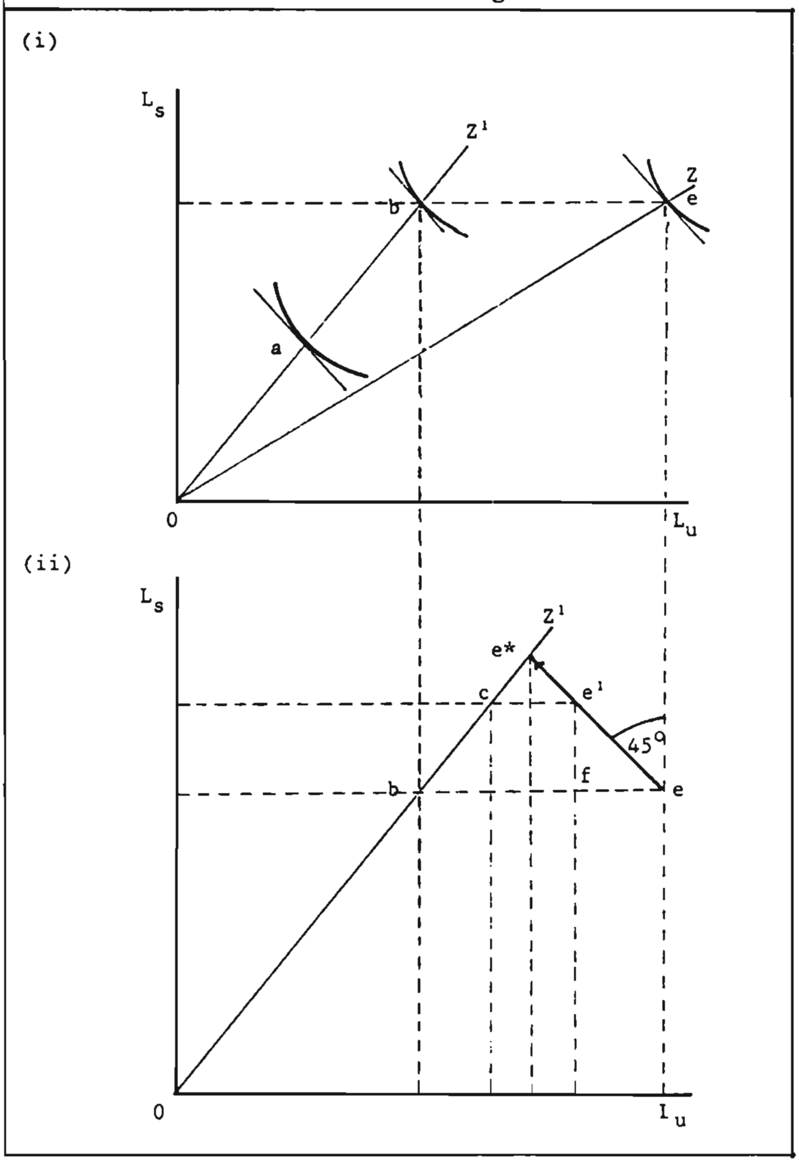
A third, and more deep-seated problem arises when shifts in the pattern of factor use lead to an incompatibility, at the aggregate level, between the magnitudes of factor requirements, on the one hand, and the magnitudes in which the economy is endowed with such factors, on the other. The example chosen to illustrate this proposition involves two types of labour since, *inter alia,* another very important aspect of technological change is its impact on the intra-factor allocation of labour. Specifically, the structural unemployment of unskilled labour due to technological change is considered.

In Figure 4(i) the point *e* represents the skill endowments of the economy: L_u units of unskilled labour and L_s units of skilled labour. It is assumed that, initially, output, factor prices, and the technology of production are consistent with full employment of both types of labour and point *e* is thus an equilibrium position. After unskilled labour-saving technological change, and assuming fixed wage relativities, the former output level is attainable with a more skill-intensive mix of labour inputs.[14] Subsequent output expansion along OZ^I is now permissible only as far as the point *b*, which represents the maximum output available with the fixed endowment of skilled workers. At this point there exists technologically-induced unemployment in the amount represented by the horizontal distance between *b* and *e*.

It is precisely for such reasons that policy analysts emphasise the importance of training and retraining programs to aid in the adjustment to the skill-mix consequences of technological change. Figure 4(ii) provides a simple demonstration of how the transformation of skill characteristics through training might be expected, in principle, to alleviate the technological unemployment problem. The point *e* corresponds to its counterpart in Figure 4(i). It is the economy's skill endowment point and shows the magnitudes of skilled and unskilled labour on the vertical and horizontal axes, respectively. The post-technological change expansion path OZ^I is also identical to that in Figure 4(i); technological unemployment consists of *be* unskilled workers.

Now consider the training process of transforming unskilled workers into skilled. It may be represented as the 45° line labelled ee^Ie^*. For illustrative purposes the employment consequences of the (re)training process are shown in two stages. In the first stage *ef* unskilled workers are transformed into fe^I additional skilled workers. The economy's skill endowment point has therefore moved to point e^I which, compared to point *e*, has fewer unskilled and more skilled workers. The additional skilled workers permit an increase in the scale of production along the expansion path OZ^I from point *b* (where output was formerly constrained by the skill shortage) to point *c*. In the second stage the process of transforming skills continues until the attainment of point e^* which lies on the expansion path and where all workers, both skilled and unskilled, are employed.

FIGURE 4
Technologically-Induced Unemployment and the Role of Training



CONCLUDING COMMENTS

The objective of this paper has been to illuminate some of the concepts relating to the employment impact of technological change using simple theoretical tools. The micro-economic perspective of section 2 shows that in theory the labour-saving bias of technological change may pose employment[15] problems. The net outcome is shown to depend on a variety of factors such as the magnitude of any associated cost reduction effects, factor price changes, and the position and elasticity of the product demand curves, *inter alia.* The magnitude of such effects is an empirical question that must be answered before prediction is undertaken: in practice scale effects may offset the adverse employment consequences of technological change, but one may not assume this on the basis of theory.

The macro section suggested that at the aggregate level the viability of compensating scale effects might be jeopardized in the short run by an insufficiency of aggregate demand caused by technological shocks. Next the maladjustment accompanying the frictional and structural unemployment effects of technological change may curtail even more the effectiveness of conventional macro policy instruments. More selective measures must be used. The theoretical potential of manpower training to redress skill imbalances was shown in Figure 4(ii). Thus in practice these theoretical issues have profound policy implications. In particular it appears that the interdependence of economic conditions and the process of technological change is such as to not only complicate the policy-making process but also to make the impact of new technology *per se* virtually indistinguishable from underlying cyclical and/or structural unemployment problems of the economy.

The issue addressed here is undoubtedly complex: one cannot confidently predict the sign, much less the magnitude of the net employment outcome of technological change. But some consequences we do know with more certainty. Whether or not there is net overall job loss or job gain for the economy, technological change is sure to bring problems of economic and social adjustment and adaptation. We know already that the required skill structure of the workforce is being transformed and we have indications as to how that transformation might proceed. We know, therefore, that a heavy burden of responsibility rests upon our educational and vocational training institutions. It is apparent also that accelerating rates of technological change will place increasing emphasis on retraining at various junctures in our worklives. If rigidities in the occupational wage structure persist, governments may need to play a role to counteract immobility. Even with wage flexibility, however, information takes time to acquire and act upon and a further gestation period is required for the production of new skills. So some dislocation and unemployment of labour seems inevitable. It can be minimised, however, if improved identification of future skill requirements lengthens planning lead-times; if educational and training institutions are geared to react in a more rapid and less Procrustean fashion; and if individuals are equipped with general skills that emphasise versatility, flexibility and adaptability.

NOTES AND REFERENCES

1. Committee of Inquiry into Technological Change in Australia, *Technological Change in Australia (Myers Report)*, AGPS, Canberra, 1980; ASTEC, *Technological Change and Employment*, a report to the Prime Minister by the Australian Science and Technology Council, AGPS, Canberra, 1983.
2. These might irreverently be described as the "doom and gloom", "she'll be right mate" and "it all depends" positions.
3. Myers Report, *op. cit.*, pp. 29-30.
4. ASTEC Report, *op. cit.*, p. 69.
5. The failure of the Myers Report to formulate its discussions within an explicit framework of economic analysis is lamented in Joy Selby-Smith, 'The Report of the Committee of Enquiry into Technological Change in Australia: A Review', *The Australian Quarterly*, 53, 2, 1981, pp. 177-186.
6. In reality, innovation may involve not only changes in the process of production, but a change in the nature of the product itself. In addition, we must recognise that technological change is not instantaneous but may involve a lengthy process of invention, innovation and diffusion.
7. For a formal and more detailed exposition of *inter alia* Hicks-, Harrod-, and Solow-neutral technical progress, see R.G.D. Allen, *Macroeconomic Theory*, Macmillan, London, 1967, chapter 13.
8. In fact, the relative price of the more productive factor is probably more likely to fall than to rise, and thus to reinforce the shift towards its proportionately greater utilisation. The perverse case is shown for purposes of illustration.
9. Michael Carter, 'Technological Change in Australia: A Review of the Myers Report', *The Australian Economic Review*, 2nd Quarter, 1981, p. 56.
10. Note, however, that had output remained at X_1 it could have been produced with only L_2 units of labour, via production function *II* — a fall in employment of L_1-L_2.
11. If the technical change involves product, as well as process innovation, changing tastes might shift the product demand curve so as to add a further dimension to the scale effect.
12. For an exposition of the "institutional" and "structuralist" interpretations of stagflation and the problems they pose for conventional aggregate demand policies, see Keith Newton and David Kalisch, 'The Australian Phillips Curve: Empirical Evidence and Policy Implications from a Canadian Perspective', BLMR (Bureau of Labour Market Research) Conference Paper No. 32, Canberra, 1983.
13. See C.M. Cooper and J. Clark, *Employment, Economics and Technology*, St. Martin's Press, New York, 1983, pp. 104-105.
14. With fully flexible wages a sufficient output expansion could, in principle, restore full employment of both types of labour. With fixed coefficients, of course, flexible wages will not help.
15. The further decomposition of employment into persons and hours and the impact of technological change on their distribution is beyond the scope of the present paper.