INFORMATION TECHNOLOGY AND EMPLOYMENT: SOME NOTES ON THE USE OF MODELLING TECHNIQUES AS A RESEARCH TOOL

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This paper presents a brief review of the use of macroeconomic models in research on the employment implications of information technology. It makes particular reference to the Austrian study, Microelectronics: Applications, Diffusion and Effects in Austria. The major conclusion is that whilst such models have a value, this is dependent on assumptions made about how technology is used rather than simply upon levels of usage or rates of diffusion. It concludes with a consideration of the applicability of such techniques in the future case of advanced and integrated systems in manufacturing and the service sector.

Keywords: employment, information technology, macroeconomic models, input-output models, microelectronics, Austria

INTRODUCTION

Despite the recession, the industry associated with making predictions about the employment effects of information technology (IT) has been growing rapidly over the past few years. It has moved from the early days of armchair speculation about the likely shape and problems of the information society of the future (e.g. Simon[1], Bell[2]), through the somewhat hysterical phase of the mid-1970s which produced books with provocative titles like *Automatic Unemployment*[3] and *The Collapse of Work*[4], to the present position which is characterised by extensive research and commentary from a wide variety of interested groups. Amongst these we should consider government, trade unions, research groups in the academic and trade world, consultants and special interest groups of various kinds; Table 1 gives some examples. It is interesting to speculate as to how much information can actually be gleaned from the mass of data collected in research; it seems to be a characteristic of the 'information society' that we actually know relatively little about it.

Within the field of research on employment there appear to be two main approaches. One is what might be called the microeconomic view which takes a deliberately disaggregated approach, concentrating on a particular sector or a specific occupational group and attempting to build up a more general picture in small increments of well-founded research. This route has the advantage of getting close to the nitty gritty of technological change in particular circumstances and has particular value in exploring policy options open at the level of individual firms, trade unions or other interested bodies. Its principal research tool is the case study — and therein lies its greatest weakness. Although studying a small sample closely may reveal a great deal about the experience of that sample, it does not necessarily tell us much about the wider experience, or about how general the results of the work are. It helps in identifying and developing hypotheses and, as already noted, it helps at local policy formulation levels. Where it is weak is in informing national level policy-making. In the case of the employment effects of IT, this weakness may be important since what it needed is national level adjustment to change.

The other approach is, arguably, more suited to informing policy-making at national level, and can be termed the macroeconomic view. Such approaches operate on the basis of statistical and econometric methods to arrive at descriptions and predictions of what is going on or is expected to take place. Their limitation is in the level to which such approaches — particularly those involving modelling techniques — can actually reflect the real world. In the case of IT it is possible, for example, to construct a macroeconomic model for employment displacement which simply extrapolates the present incidence of job displacement from the relatively few cases which we have to a figure assumed to apply across all sectors and into the future. Such a model takes no account of variations in the experience of IT at different levels of the economy, nor of intervening variables such as economic growth, government or trade union influence; in short, it is so severely limited as to be useless — and possibly dangerous if it is used to formulate policy.

The major difficulty facing modellers is that of variety; in theory, the only model which will accurately describe and predict will be one which matches the variety of the real world — and even with advanced computer techniques and expert systems, that is some way off. This is not to argue for the rejection of macroeconomic models, but merely to indicate that their construction and use need to be carried out carefully, otherwise we are likely to be reduced to simple formulations like "one word processor costs one job, therefore ten thousand word processors cost ten thousand jobs". These clearly provide no basis for policy-making.

TABLE 1

Examples of research on employment and information technology

(a) Government studies	
	Sleigh *et al.*[5]
	Manpower Services Commission[6]
	Nora and Minc[7]
	Myers[8]
	Rathenau[9]
(b) Trade Unions	
	TUC[10]
	European Trade Union Institute[11]
	European Pool of Studies[12]
	APEX[13]
	ASTMS[14]
(c) International studies	
	OECD[15]
	ISI[16]
	UNITAR[17]
(d) Studies of sectors, areas, occupation and social groups	
	Green and Coombs[18]
	EOC[19]
	Senker and Swords-Isherwood[20]

Fortunately there is a respectable body of work on macroeconomic modelling[21] and the efforts of these workers have led to the development of approaches which permit models to deal with complex interactions and interdependencies in the economy with some success. One of the most significant attempts in recent years in the field of macroeconomic modelling applied to employment research has been the study funded by the Austrian government, *Microelectronics: Applications, Diffusion and Effects in Austria*[22]. This paper considers this work not from the standpoint of economic modelling (which has been dealt with elsewhere), but from the point of view of its contribution to the debate on employment implications of IT.

THE AUSTRIAN STUDY

Commissioned by the Ministry for Science and Technology, the project was a collaborative venture involving two major research institutes, OIW and OAW[23]. It brought together a large team of researchers who, together with interested industrialists and civil servants, managed to cover a great deal of ground in a short time. Throughout the work was conceived of as policy-oriented rather than as an academic exercise; the intention was to use its findings to inform government policy-making in a number of areas which might help Austrian adjustment to the challenges posed by IT. In terms of the formulation of the model, this was of major importance because it meant that from the outset the team was concerned with the development and exploration of realistic scenarios for the country.

In terms of content the report begins with the usual introductory material covering the emergence and extent of the 'microelectronics revolution' — development of the transistor, structure of the world semiconductor industry and market applications in products and processes and a consideration of some of the technological and microeconomic aspects of introducing microelectronics.

From here it moves to a specifically Austrian focus, looking at the range of applications (existing and likely) in various sectors of the economy and giving a broad overview of the likely implications for productivity of changing to IT — again, based on local and real applications data from early users. This leads into the centrepiece of the work — the development and application of a macroeconomic model relating productivity, employment, technical change and other parameters. Data for the model come from a national input/output data bank; the main difference between this model and other macroeconomic models for employment is that although it is designed along relatively standard input-output analysis lines, the coefficients of various parameters have been chosen to reflect the changes likely to arise as a result of the introduction of information/microelectronics technology.

It can thus be seen that the success or failure of the model depends to a large extent on the selection and applicability of these coefficients. Fleissner, one of the members of the original team, suggests that the model can in fact be used to cover the impacts of any technological change — " . . . if this technology can be explicitly connected with certain economic indicators like productivity, manpower, material inputs and outputs".[24] As we will see later, this "explicit connection" is of critical importance in determining whether the model provides useful and relevant data.

The model is used to examine five major alternative scenarios for the Austrian economy, reflecting a range of possible futures. These are:

- rapid diffusion, assuming a constant working week based on 1980 hours;
- slow diffusion and assuming a shorter working week;
- shorter working week and domestic manufacture of microelectronics and IT based products rather than importing them;
- reduction in numbers seeking employment (due to early retirement); and
- full diffusion of microelectronics.

Each scenario is developed through the model and there is considerable interaction and feedback; so, for example, the results of scenario 3 suggest the possibility of economic growth through export success in microelectronics, which will affect other parameters and modify other scenarios.

Although policy-making requires some indication of quantitative changes to be expected, the report does not confine its analysis to this set of model-derived numbers. It moves on to discuss the likely qualitative implications and particularly those for the structure and development of education policy. There is also some discussion of the impact on work organisation and other related workplace issues. This is significant, in view of the importance attached to the concept of 'quality of working life' — which in Europe is often backed by legislation, such as the Humanisierung der Arbeit programme in West Germany. One of the other valuable contributions of the report is that it then attempts to generate another set of scenarios — related to the first, numerically derived ones, but this time based on a more wide-ranging qualitative database compiled from expert opinion, case study research, literature survey and so on. These suggest likely futures and examine the context of anticipated technological/sociological changes. The scenarios are:

- favourable economic climate, technocratic approach;
- unfavourable economic climate, technocratic approach;
- favourable economic climate, participative approach; and
- unfavourable economic climate, participative approach.

In this way it is possible to examine what technological change is likely to mean for Austrian society and under what conditions it is most likely to succeed to everyone's benefit — and equally, the limitations of other societal arrangements.

The report concludes with an overview of the integrated picture, pulling together the data from the two sets of scenarios and other relevant information which describes the likely future for Austria and the needs for social, technological and economic policy.

STRENGTHS AND WEAKNESSES OF THE STUDY

This paper is not concerned with a critique of the modelling techniques used but with the contribution the work has made to the debate about employment and microelectronics. In this assessment it must first be said that since its publication the report has received a generally favourable press from researchers and others interested in the field, including, for example, Leontief.[25] However, the real test of a piece of policy-oriented work of this kind must be whether it actually has an impact on policy. In this particular case the answer is very much in the affirmative; a number of important actions have been taken by the Austrian government in response to the study, particularly in the area of educational policy (with emphasis on improving the responsiveness of the system, both to provide scarce skills and to meet the demands of a population with a growing amount of leisure time).

Clearly the model approach works in Austria, insofar as it has produced sufficiently realistic predictions to convince policy-makers to embark upon actions which are often more far-reaching and long-term in their emphasis than most other European states. Whilst we cannot yet say whether these policies — and, by extension, the study itself — have actually helped Austria adapt to the microelectronics revolution, the level of unemployment in the country is one of the lowest in the Western world. Clearly it has not hindered things. More important, estimates made by the model have been confirmed in subsequent microeconomic studies; this suggests strongly that the model approach is a valid technique for employment research. The question is, how far is the Austrian case one from which more general conclusions can be derived? And, following from this, is the technique applicable elsewhere?

At first sight the Austrian economy does seem to be a special case; small, well-managed and healthy — even during recession — and with one of the best employment records around. Being small also helps, insofar as the relevant data for input-output analysis is relatively easy to obtain and use. To this must be added the long and respectable tradition of economic research in Austria which has a reputation for thoroughness and discipline. Such a combination of factors might be considered peculiar to Austria, thus limiting the applicability of both the technique and the results. Closer analysis reveals that, although small, the economy is actually very diverse — and some economists believe that it can be used as the basis for extrapolation. For example, Leontief argues that

> The Austrian economy is a mere 3 per cent the size of the US economy, but it too is highly industrialized and diversified. With some stretch of the imagination the Austrian projection of a high degree of mechanization supported by rapid expansion of domestic manufacture of all kinds of electronic products can be interpreted as indicating the structural changes the US economy is likely to undergo in the next 10 to 15 years.[26]

A more serious question concerns the availability and use of input data for the model. Although macroeconomic data may be available from national data banks of input-output tables, other forms of data — such as realistic assessments of technological potential and capacity and likely rates of innovation — are much more difficult to obtain. One of the admitted weaknesses of the study is that it based its modelling on 1980 figures and data, and already, within three years, many of the technological elements have been rendered obsolescent by developments in what is an extremely fast-growing industry whose compound growth rates are around 20-30 per cent per annum.[27]

WIDER ISSUES

Although the pattern of employment implications of microelectronics is still not clearly established, there is no doubt that some progress has been made since the somewhat hysterical early phase of the debate in which the massive employment displacement associated with industries like telecommunications equipment, watches and cash registers was assumed to be about to happen in every economic sector. Recession has clouded the issues, but the results of various studies — both microeconomic and macroeconomic in approach — have begun to indicate some convergence.

In particular, it is becoming clear that the existence of a technology with the capability to make significant productivity improvements across a wide range of industrial sectors and activities within those sectors does not, of itself, mean that such change will actually take place. The evidence points instead to a pattern in which it is not so much the technology as how it is used which determines productivity changes — or, for that matter, other changes such as those in the pattern of skills required, work organisation structures and other qualitative issues. Significantly, this pattern has been observed in a wide and growing number of sectors involving a number of different applications of the technology.

Considerable research has been conducted on the introduction of computer-numerically-controlled (CNC) machine tools, looking in particular at the patterns of work organisation, skill distribution and manning levels associated with this innovation. The results suggest that, contrary to the 'technological determinist' type of argument, which would anticipate high division of labour, reduction in manning levels and deskilling of operator tasks, there is, in fact, a wide range of choice available to firms implementing the technology. A study in West Germany, for example, found that out of a sample of 300 firms no less than five economically justifiable arrangements were in use. This finding is confirmed by other workers, for example, Wilkinson[28] and Sorge *et al*[29], who comment,

> . . . all our results serve to stress the extreme malleability of CNC technology . . . there is no effect of CNC technology as such . . . the malleability of CNC technology shows in the fact that its technical specification in detail and its organisational and labour conditions are closely adjusted to company and departmental strategies, existing production engineering and organisation strategies and manpower policies.

Similar results have been found in other sectors involving other technologies — for example, Boddy and Buchanan[30], Bessant and Dickson[31], and Winch[32].

In the case of industrial robots, rates of diffusion are rapid and appear to be accelerating.[33] Yet studies of the introduction of robots reveal that labour-saving is rarely the dominant motive (although this may reflect in part a short-term concern with industrial relations implications of 'robotising' work), and the actual level of labour displacement is far less than might have been expected from early commentary.[34] In the case of word processors and computer equipment, Mandeville and Macdonald[35] found

> a very rapid diffusion (of word processors) . . . and yet little reduction in the total number of typists and stenographers . . . similarly, our studies of computer usage in small business and in local government discover little evidence of direct job losses as a consequence of computer adoption.

Their Australian findings are supported by UK studies such as that of Steffens.[36] In banking, where investment in new technology has been very large, both in direct customer services such as automated telling machinery (ATM), and in behind-the-scenes applications such as electronic funds transfer systems, the actual level of employment has grown. Whilst this must reflect the continuing expansion of the sector and the secular trend of 'jobless' growth, it does indicate that IT has not had the exacerbating effect predicted in earlier studies.[37]

These and other studies confirm the view that it is not simply a matter of investment in technology which determines employment or productivity effects, but rather a complex inter-relationship between innovation and innovating organisation. It is worth extracting some important points from work on the diffusion of microelectronics in this context. First, it is clear that such innovations are almost never introduced for a single motive — such as labour-saving; adoption is related to a combination or cluster of perceived attributes. Second, it is the fit between these attributes and a similar set of organisational attributes which is largely influential in determining adoption — and this pattern varies considerably among firms and over time. Certainly it is the presence of a good fit between these two groups of factors which determines successful adoption and implementation.[38] Third — and for our purposes, most significant — there is a wide range of choice around which the introduction of new technology is negotiated. This room to manoeuvre — which has been called 'design space'[39] — has a number of components which include, in addition to economic and technological considerations, a host of organisational issues — industrial relations, traditions of innovation, company strategy, relationships with internal and external groups, and so on.

All of this suggests that in considering the employment or productivity implications of technological change there is a need to take account of the implementation issues rather than assume a direct transition between technologies. Within macroeconomic modelling there is little room for such considerations except, perhaps, under the general label of 'learning effects' — but from the above research evidence it is clear that they are of central importance to understanding what is actually happening. They affect both the level and timing of change; for example, Arnold[40] found that the time lag between adoption of computer-aided design technology and achievement of 'best practice' in terms of design productivity was, on average, eighteen months to two years.

This is perhaps the major weakness of taking a macroeconomic modelling approach to employment research. In the final analysis, the assumptions made about, say, productivity changes to provide input data for the model are, in fact, also assumptions about the way in which technology is used. But we know from experience that this is a complex variable, determined by a whole range of factors — and therefore unlikely to be amenable to simple modelling techniques. Fleissner's comment about the potential applicability of the Austrian model to other economies and technologies, for example, is perfectly valid — but it depends critically on getting the inputs right. And the inputs are going to be modulated by choices about implementation which may not be amenable to modelling. Thus the model — or any other macroeconomic model — is only as good as its set of assumptions about the use of technology.

In practice this need not be too big a problem. Although the above indicates a potentially wide range of choices in the use of technology, in practice the majority of firms make similar choices from a relatively small number of opinions; for example, the five modes of CNC use found in West Germany. So it may be possible to incorporate such data in the model and generate meaningful scenarios which can be checked back against empirical microeconomic research data to obtain the best fit in terms of descriptive validity. The key point here is that the modelling research project cannot operate in isolation; it must relate to other data sources. This is the strength of the Austrian project, which was built up as a multiple method forecasting study of which the macroeconomic model was the centrepiece — but not the only piece — of the research. Data were also collected from literature surveys, case studies, expert panels and so on. Such multiple method approaches follow what Denzin[41] calls a philosophy of 'triangulation' — of arriving at the same conclusions by a series of different but mutually-reinforcing methodological routes. When such triangulation does not take place, the resulting predictions from a macroeconomic model must be limited; the critique by Mandeville *et al*[42] of the IMPACT study in Australia highlights such a problem.

MODELLING THE FUTURE

So far this paper has considered generations of information technology which are reasonably well-established and essentially of the kind covered in the 1980 base of the Austrian study. However, in considering the use of macroeconomic modelling as an aid to employment research, it is important to examine its appropriateness for the next generation of automation technology as well.

Automation has so far followed a path which can best be described as "advanced mechanisation"; that is, although the individual items of information technology are impressive in themselves and represent a considerable improvement on conventional technological solutions, they are still largely discrete replacements for earlier mechanical generations. In other words, they make their main contribution by helping industry do what it does better. But this poses the question whether doing things better is the best that can be done — particularly when the considerable potential of information technology is taken into account.

The question is rhetorical; what is now beginning to emerge is a pattern of second generation automation which makes much more extensive use of the properties of information technology — often with radical implications for the design and structure of industrial operations. This can be seen if we consider briefly the 'factory of the future' in which IT is fully exploited. Manufacturing can be conceived of as involving three basic groups of activities — pre-production work (including design, production planning and procurement), production itself (assembly, forming, processing, etc.) and management of production (planning, scheduling, optimising, etc.). Within each of these areas automation has made considerable progress and IT-based systems are widespread. In recent years there has also been a growing incidence of what Kaplinsky[43] calls 'intra-sphere' automation, in which different components within the same area are integrated into a single system. For example, in production the early principle of a single machine for each operation in the engineering industry has given way to first automated multi-function computer control of individual machines and then to highly complex machining centres with the capability of carrying out tasks normally done by three, four or five conventional machines.

The next step — and one which is increasingly being taken in manufacturing industry — is to integrate between different spheres of activity. Thus the design field is directly linked with production and management in so-called 'computer-integrated manufacturing'. An early example of such CIM is what is termed a 'flexible manufacturing system' — a technology which is emerging in metalworking but which has potential as a concept in many other areas of manufacturing. In a FMS a range of machines is used to make small batches of parts economically. Production planning, monitoring and overall management is handled by a central computer which passes instructions to each machine about what it should be making, and monitors its progress. Stockholding and materials handling are carried out by robots or programmable conveyors, also under central computer control. Data on the design of particular parts is sent electronically from computer-aided design systems to the central computer and thence to the relevant machines in the form of operating instructions for making that part. The idea is that the whole operation is integrated under computer control, and the system works with very high levels of responsiveness and flexibility; in other words, although a complex assemblage of different machines and systems, it behaves as if it were a single total production machine.

Such models are fast becoming reality — but they pose major problems for firms trying to introduce them. Quite apart from the high capital costs and the difficult technological problems (such as getting various computers and machines to talk to each other intelligibly), there is a host of organisational issues involved. What is required is a major adaptation to a completely new mode of operation — and all the evidence so far suggests that these are the key ratelimiting problems in the diffusion of such advanced integrated automation. Amongst those involved with installing the present generation of FMS there is a consensus that the technology will require a completely new way of thinking about production.

Significantly, it may in fact be the new approaches to production organisation that offer most of the benefits in future manufacturing systems; one report suggested that as much as 60 per cent of the benefit of FMS introduction could be achieved without installing a single piece of new technology.[44] Clearly under these circumstances any considerations of productivity changes must be placed in their organisational context; thus any future modelling must try and take these aspects, as well as the directly technological, into account.

Similar patterns exist in the service sector. Much has been said about the so-called integrated office of the future, but in fact we are still at the stage of office mechanisation. Although the spheres of processing (of text, data, voice, etc.), communication and database can potentially be integrated, in practice this is going to take some time to emerge. This is not a technological problem but — as in the manufacturing case above — essentially one of organisational change and adjustment. In both cases the key to productivity improvements will be in the organisational rather than the technological dimension.

That being the case, it is clear that predicting the employment effects of second generation automation will be extremely difficult, especially via macroeconomic modelling techniques. Focussing on the technology alone is likely to lead to increasingly erroneous results, especially as the integration of systems takes place. As we have seen, even with present generations of discrete automation such modelling has its limitations; as we move to integration so these errors are likely to be compounded.

This is not to reject such approaches for the future; on the contrary, as we have seen in the Austrian case, they have an important role to play in forming policy development for dealing with technological change. However, it is critical that such techniques operate on the basis of triangulation — of integrating data from different sources — so that the overall research findings can be located in their appropriate organisational context. Failure to do so will result in increasingly irrelevant predictions and a loss of faith in what is, potentially, a valuable research and policy-making tool.

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