THE EFFECT OF COMPUTERISATION ON THE DEMAND FOR LABOUR IN THE U.K.

P. Stoneman

NUMBER 47

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

UNIVERSITY OF WARWICK
COVENTRY

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This paper is circulated for discussion purposes only and its contents should be considered preliminary.

The Effect of Computerisation on the Demand for Labour in the U.K.

This paper presents the results of an exercise, based on some tentative estimates of labour saving in computer use and construction, designed to illustrate how the effects of technological change ought to be considered not solely in terms of comparative statics but also in terms of the effects during the process of changing technique, i.e. along the transition path.[1]

The study concentrates on demand for labour aspects because these can be most readily observed. The method is to consider a comparison path that is the U.K. economy frozen in its 1954 technological form with a given 1954 final demand vector, and to compare its labour demands with the actual economy (in which computerisation has taken place) once the expansion in its final demand vector has been removed. We can therefore illustrate the effect on the 1954 economy of 100% computer penetration and the effects at each stage on the transition path as the economy approaches the saturation level.

We assume that changes in the final demand vector have led to 2½% p.a. compound growth in the output level since 1954, and that to reduce the real economy to compare with the comparison path we can simply deflate by the growth multiple. This is an heroic assumption that also ignores annual variation but there is some justification.

a) The estimates to be used concern mainly the demand for labour in office applications for computers, and the Department of Employment

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(1) This paper is based on results arising from a Ph.D. Thesis submitted to the University of Cambridge, October 1973:- P. Stoneman, On the change in techniques - a study based on spread of computer usage in the U.K. 1954-1970. I wish to thank Dr. R. M. Goodwin for his advice during the preparation of that thesis and thus this paper. Thanks are also due to a referee of this journal, Professor K. Cowling of the University of Warwick, and other members of the University of Warwick Industrial Economics Workshop.

estimate that without computers, office employment would grow at 2.4% p.a.[1]

b) Although the use of computers may itself be output expansive, it has been estimated[2] that up to 1964 any such effects on labour demand were small but this problem is considered further below.

This paper proceeds as follows. In section II we estimate labour savings per machine in computer use. In section III the change in labour requirements in capital goods construction are studied. Both sets of estimates being those appropriate to third generation computer technology. In section IV a comparative statics exercise is performed, in section V the transition is analysed and in section VI qualifications and conclusions are stated.

II

Computers are used in three main areas - scientific, process control and administrative applications.[3] The break down of usage is presented in Table 1.[4]

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(1) Department of Employment, Computers in Offices 1972, Manpower Studies No. 12, H.M.S.O. 1974, p.49 para 37.

(2) Ministry of Labour, Computers in Offices, Manpower Studies No. 4, H.M.S.O. 1965, p.19 para 8.

(3) A number of studies of the effect of computers in different areas have been made. At the firm level reference to Memoranda by Rolls Royce, B.E.A., GEC-Marconi, UKAEA, Ministry of Defence, Barclays Bank, Midland Bank, Esso Petroleum, Shell Petroleum etc. to the Select Committee on Science and Technology Subcommittees A & D, (H.C. 137 & 272, 1969-70, and 621-I, 621-II, 621-III, 1970-71) H.M.S.O. is informative. At the industry level publications by the National Computing Centre e.g. Computers in Vehicle Scheduling, 1969; Computers in Textiles 1968, indicate the effects of computers on specific industries. At a more general level one can look at; Manpower Aspects of Automation and Technical Change, OECD 1966; Economic Aspects of Automation, U.N. Economic Commission for Europe, New York 1971; I. Traviss (ed.), The Computer Impact, Prentice Hall, 1970.

(4) Computers in Offices 1972, p.11. Educational and other machines are ignored for the purposes of this exercise.

Table 1 - Computer usage 1969[1]

Area of Use	Number of machines
Administrative	2,108
Scientific	600
Educational	150
Process Control	150
Others	100

Thus in 1969 approx. 2/3rds of all machines by number were used for administrative tasks. As process control machines tend to be small their relative importance is reduced. These proportions have probably changed over time with scientific applications reducing in relative importance. This will be referred to in the final section.

We argue;

a) The use of process control computers has no implications for labour demand in the user sector,[2] and is purely capital saving;

b) Scientific applications do not save labour but generate new knowledge;[3]

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(1) The table only covers machines costing £20,000 plus. This exclusion is of little importance (see, Computers in Offices 1972, p.46 para 9).

(2) Select Committee on Science and Technology Subcommittee D, The U.K. Computer Industry, Vol. II, HC 137, (Session 1969-70)H.M.S.O. 1970, Memorandum by Ferranti Ltd., p.76.

(3) Although in certain cases e.g. aircraft design, scientific machines may be considered labour saving, much scientific work could not even be carried on without computers and thus this assumption seems reasonable.

c) Labour implications are concentrated in the use of computers for administrative purposes.

The pattern of labour saving in administrative use can be identified as in Table 2. The derivation of this table is covered in the Appendix.

Table 2 - Posts replaced and created per computer installed 1964 and 1969.

Occupation	Number of Posts	
	1964	1969
Managers & Executives)	- 1.0	- 1.0
Supervisors)		- 5.0
Clerks	-47.3	-49.0
Typists	- 3.4	- 7.0
Calculating Machine Ops.)	-20.7	-12.0
Other Office Machine Ops.)		- 5.0
Other Office workers		- 1.0
D.P. Managers	+ 1.1	+ 1.3
Systems Analysts	+ 3.7	+ 5.4
Programmers	+ 5.6	+ 7.4
Machine Operators	+19.1	+20.1
Other EDP staff		+ 5.1
Net reduction	42.9	41.6

If we capitalise skill differences by one man year of labour per year of operation[1] we can identify a labour saving of 41 man years per computer (per year of operation) in administrative applications.

We spread this saving over all computers making (with rounding) 27 man years of labour saved per year of operation. We estimate that a

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(1) This estimate is based on information in, Civil Service Department, Computers in Central Government Ten Years Ahead, CSD Management Studies 2, H.M.S.O., London 1971, pp93-6.

computer has an active life of 7 years[1] but takes one year[2] to install, and can therefore present the pattern of net labour use in computer applications as

Year	0	1	2	3	4	5	6	7
Net Lab Use	0	-27	-27	-27	-27	-27	-27	-27

III

In capital goods construction we require estimates of labour use in the construction of computers and capital goods for replaced techniques. We have derived (see Appendix) that each computer requires 50 man years of labour input spread over two years for construction. Replaced machinery, mainly office machines and special logging and control equipment[3] requires 2.0 man years of labour input. Thus in capital goods construction, we can identify net labour use, with time measured relative to computer use, as

Year	-1	-2	0
Net Lab Use	+50	+48	0

Thus generating the profile of net labour use as

Year	-1	-2	0	1	2	3	4	5	6	7
Net Lab Use	+50	+48	0	-27	-27	-27	-27	-27	-27	-27

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(1) Using data from Computer Survey, United Trade Press, London, 1962-1970, approximately 70% of machines have died by the end of their seventh year. Some live for 10 years or more, some only for two years.

(2) For the time profile involved in the computer installation time profile see the two Computers on Offices surveys, Appendix 9 in the 1965 volume, and Appendix 13 in the 1973 volume.

(3) For details of machinery replaced see the Evidence of Ferranti to the Select Committee op.cit., Computers in Offices, p.15, and Computers in Offices 1972, p.14.

IV

To compare economies with and without computers we need an estimate of the satiation stock of computers. To get round this problem the projections of the growth rate of the computer stock generated by the Department of Employment[1] are used for the period 1971-1978, and then 1979 and 1980 are assumed to have a stock 3 and 2½% greater than the previous year respectively. Assuming that the economy has been growing at 2½% p.a., the 1980 economy is considered to be computer saturated. However the calculated 1980 stock is relevant to the 1980 economy and we wish to effect a comparison with the economy with the 1954 final demand vector. Thus the assumed rate of growth of 2½% is removed from the data so that the recalculated 1980 stock is now the saturation stock for the economy with the 1954 demand vector. On the basis of an actual 1970[2] stock of 5,470 machines the calculated saturation stock is 8,092 machines.

Assume now that these machines, for comparison purposes, would have an even age spread at 100% penetration so that a constant proportion would come up for replacement each year. To produce these replacements the economy would require an extra amount of labour equal to,

$$\frac{1}{8} \cdot 8092 \cdot 48 = 48{,}552$$

and would save in each of the seven years of operation twenty-seven men per machine, i.e. in each year the economy would reduce its labour demand by

$$\frac{7}{8} \cdot 8092 \cdot 27 = 194{,}970$$

This would mean a net reduction in labour demand of 146,418 man years.

(1) Computers in Offices, 1972, p.10.

(2) Derived from Computer Survey.

This is approximately ½% of the 1954 labour force.

V

Turn now to the transition path. Here one is concerned with the changes that the 1954 economy must go through in order to reach the computerised state. It is felt that the best way to do this is to investigate the actual time path of computerisation since 1954 considering 1952 as year zero, remove expansion from it, and then say that each time period represents a stage on the transition path.

The expansion effects are removed by assuming the 2½% p.a. compound growth in output since 1954 and that to reduce the actual stock in time t to the transition stock in time t one can simply reduce the stock by the compound growth multiple. The 1954-1970 transition stock, i.e. the years 2 - 18, can be easily derived from the actual Computer Survey data. For the years 1971-1980 the Department of Employment growth rates, reduced by 2½% p.a. are used.

To generate the labour requirements in computer manufacture it is necessary to generate a series of gross additions to the computer stock. For the years 1962-1970 gross data is available from Computer Survey. In other years it is assumed that machines are replaced at the end of the seventh year of their operation.(1) To get to transition path gross additions it is assumed that the transition gross additions bear the same relation to the transition net aadditions as do the actual gross additions to actual net additions.

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(1) This assumption is not totally consistent with the relationship of gross to net in the actual data, and has the unfortunate outcome of producing "echo" effects in the latter part of the series calculated. Attempts to estimate decay functions were unsuccessful, and this necessitates the present assumption.

With the stock, gross additions, and the time profile of labour savings for each computer as detailed above, one can calculate the savings made on the transition path. These are presented in Table 3. If one assumes that only 70% of machines are constructed in the home country[1] a different set of savings result. These are also detiled in Table 3. The manner of generating these figures is that if T is taken to represent calendar time and t to represent time internal to the process, then if one lets a_t be the net change to labour requirements in time t the total addition to labour requirements will be

$$\sum_{t=2}^{o} x\ (T - t)a_t$$

where x(T) is the number of gross additions to the stock in time T. The total reduction in labour requirements will be in time T

$$(S(T) - x\ (T)).27$$

where S(T) is the total stock in time T.

It will be noted that the labour savings in the year 1980, by which time the satiation stock has been established, do not match those calculated in the comparison of states above. This can be explained by the fact that in that comparison an even age spread of equipment was assumed whereas in the present situation this stage has not been reached. This is however only part of a wider question, for although a path has been detailed for 28 years the transition is not complete. A transition path is concerned with the path between steady states. No such position has been established. The next stage in the path must be the taking up of the labour released and

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(1) This percentage is derived on a basis shown in the Appendix.

Table 3 - The Transition Path of Computerisation

Years along Transition path	No. of machines Stock	Net Addition	Gross Addition	Increase in Labour Usage	70% incr. in Labour Usage	Reduction in Labour Usage	Balances 1	2
0				300	210	0	300	210
1				501	350	0	501	350
2	12	12	12	582	407	0	582	407
3	21	9	9	1370	959	324	1046	635
4	36	15	15	2493	1736	567	1926	1169
5	71	41	41	2576	1804	972	1604	832
6	139	62	62	2708	1896	2079	629	- 183
7	185	46	46	3893	2724	3753	140	- 1029
8	251	66	66	6585	4609	4995	1590	- 386
9	334	83	95	9248	6474	6453	2795	21
10	484	150	176	9949	6970	8316	1643	- 1346
11	667	183	208	16411	11488	12393	2018	- 905
12	731	64	207	17193	12035	14148	3045	- 2113
13	1165	434	466	19682	13777	18873	809	- 5096
14	1386	221	259	30352	21246	30429	- 77	- 9183
15	1794	408	549	42782	29948	33615	- 9167	- 3667
16	3276	582	709	44882	32017	45009	- 127	- 12992
17	2887	511	1059	39458	27621	49356	- 9898	- 21735
18	3513	626	821	39054	27337	72684	- 33630	- 45347
19	4128	615	823	43740	30618	89234	- 45494	- 58616
20	4726	598	805	43507	30455	105867	- 62360	- 75412
21	5269	543	1009	49126	34410	115020	- 65894	- 80610
22	5822	553	812	64389	54072	135270	- 70881	- 90198
23	6491	669	1218	73515	51460	142371	- 68856	- 90911
24	7237	746	1455	64171	44920	156114	- 81943	-111194
25	7780	543	1602	46714	32699	166806	-120092	-134107
26	8052	272	1093	39947	27981	187893	-147919	-159912
27	8092	40	863	43740	30618	195183	-151443	-164565
28	8092	0	805	43507	30455	196749	-153242	-166294

also the generation of a more even age spread of equipment. No further investigation is to be carried out here though.

One conclusion that can be reached, however, is that the transition path is really more interesting than the comparison of states, for, although it has been abstracted from, while this computer transition has been occurring other diffusions will have been taking place and new innovations made. A comparison of steady states which economies never reach could not indicate what effect these processes are having on the economy. It is more interesting to discover what effect the computer has had on the economy during its transition path than to derive what effect it might have when the transition is complete. The fact that at some date the use of computers may release ½% of the labour force is less important that the fact that during the first 15 years of its life the computerisation process has generated an increase in labour demand.

VI

We can make a number of qualification of our results.

a) As well as the labour savings being produced by computers, benefits ranging from space saving, increased efficiency, better service etc. can also be identified.(1) There are also implications for the skill structure of the labour force and its distribution between capital goods and consumer goods industries.

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(1) For further details of such benefits as are available, see for example, National Computer Centre, The Analysis of Computer Usage in the U.K. 1971, Manchester, 1971, pp 14-21.

b) The proportions of computer use[1] have changed over time. In the initial stages computers were used more in scientific than administrative applications and process control is relatively more recent. As scientific machines are not essentially labour saving, but still have to be built, one would expect the stage on the transition path showing labour saving to be underestimated in terms of the size of the increase in the demand for labour and also perhaps the length of the period for which there is an increase in labour demand.

c) The technological change that has occurred in both computer use and construction has been ignored. In essence the coefficients of the technique as calculated have referred to third generation computer technology. Technological change in computer use has centred around the types of applications. In the office area there have been three stages of use - automated clerk, integrated systems and management information systems. This has meant that by concentrating on the later stages we may have overestimated the labour savings to be derived from computer use in the early years. At the same time technological change in computer production may mean that we have underestimated labour requirements for construction in the early years. Both qualifcations would enforce the conclusion that computerisation increased the demand for labour in the early years.[2]

d) There is considerable evidence that economies of scale exist in computer construction and computer use.[3] This has certain implications

(1) i.e. as detailed in Table 1.

(2) For details of the technological changes that have occurred see, for example, S.H. Hollingdale and G.C. Tootill, Electronic Computers, Penguin 1970; C. Freeman, 'Research and Development in Electronic Capital Goods', National Institute Economic Review, Nov. 1965 pp. 40-91; OECD, Gaps in Technology - Electronic Computers, Paris 1968; and P. Stoneman op.cit.

(3) See for example, C.F. Pratten, Economies of Scale in Manufacturing Industry, University of Cambridge, Department of Applied Economics, Cambridge University Press, 1971, pp. 218-26, for computer construction, and in computer use the relation between computer size and labour impact is detailed in J.D. Humphries, 'Future Staff Needs', National Computing Centre Newsletter, February/March 1970, p.12. See also P. Stoneman op.cit.

for our estimates. The technological coefficients are based on 1968 for computer manufacture. At this date the scale at which the industry was working was much greater than in the earlier years. This may imply that our estimates of labour demand in those years may be too low. In computer use we have found that net labour requirements did not change much between 1963 and 1968, but computers increased in size between these years.(1) This implies that any scale effects are not being reflected in net labour saving. It may therefore be that scale effects are being reflected in the benefits detailed in (a) above. However this increase in the average size of machines may offset the possible errors introduced by ignoring scale effects in computer manufacture, the estimates of labour demand being based on assuming machines of the same size being produced in each period.

e) Finally, we have assumed that every machine installed is for replacement purposes rather than to generate expansion of output. This does not reflect on our technological coefficients but may reflect on the total net labour demand figures generated. If machines are installed not for replacement, but, for example, to increase the management information available for use in production of a given final demand vector then there will not be any labour savings to offset the demand for labour for computer construction and use. This would imply that our demand figures are again an underestimate.

The principal conclusions to be drawn, given the tentative nature of our estimates are twofold.

a) If we make a comparison of states then computerisation can be seen to reduce the demand for labour.

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(1) In terms of all performance characteristics e.g. speed, store size etc. See P. Stoneman op.cit.

b) If we look at the transition path then we can see that the rate of diffussion has been such as to require the economy to increase its labour force for a number of years before the labour savings can be realised.

These conclusions suggest that if one is to look at the effects of technological change then one ought to really concentrate on the transition path. Moreover if one considers also that approximately 30% of computers were imported, then there are different implications for the availability of labour to provide the exports for payment when the early stages of the transition path are compared with the later.

Finally it should be stated that this analysis is really only partial. We have not analysed all the ramifications along the transition path. We have taken the computer diffussion pattern as given, we have not really analysed the interactions between the computer sector and the whole economy. Nor have we analysed how the released labour is to be taken up. To do that a much wider approach has to be taken. One way forward has been suggested by Hicks,(1) to whom, it will be clear, this paper owes a debt of methodology.

P. Stoneman

University of Warwick

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(1) J. R. Hicks, Capital and Time, Oxford University Press, 1973.

Appendix

In this Appendix the method for estimating Table 2, and labour use in computer and replaced technique manufacture are covered.

1. Net labour saving in computer use

The data available comes from the two Computers in Offices surveys. In the 1965 survey an estimate is made of the extra posts that would have been needed in the A.D.P. area to cope with the expansion of business if A.D.P. had not been available to deal with it,plus the posts actually discontinued in the A.D.P. area.(1) The survey estimates 703 computers installed or on order on the 1st January 1964, this figure being used to reduce the data to savings per computer. These data are detailed in Table A.1. To a certain extent these figures include work that would not have been done without a computer. The difference in terms of man-power was small however.

In the 1972 study those installations that had had a computer for more than two years were asked,'if you did not have your computer installation, how many additional office workers would you require to maintain your present level of business ?' Work which could not be done without the computer and which would therefore have to be abandoned was specifically excluded. The number of posts per computer in well established institutions are detailed in Table A.1.(2) It was also estimated that small computers (costing less than £20,000) had absorbed another 2,000 posts and computer service bureaux a further 12,500. This 14,500 in a total of 158,000 posts would only slightly modify the numbers overleaf and because of the possible errors in estimation(2) and difficulties of breakdown, are ignored.

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(1) Ministry of Labour, op. cit., p.19 , Table 1.

(2) Department of Employment, op. cit. p.20 , Table 7.

To offset these reductions in office posts there have been posts created by A.D.P. For the estimation of these figures the Computers in Offices surveys were used again. For 1964, the survey made distinction between permanent and transitional employees, this has been ignored for the 1972 study found that the transitional employment became permanent.(1)

Table A.1

Posts taken over by computers

	1964	1969
Management & Executive	1.0	1.0
Supervisors		5.0
Clerks	47.3	49.0
Typists	3.4	7.0
Machine operators	20.7	17.0
Others	-	1.0

Because service bureaux and manufacturers service to customers provide much software to users, it was decided to include labour in these sections when calculating posts created. This meant that the posts per computer were worked out on the basis of the 703 owned or on order by customers plus the 58 in service bureaux. From the survey, the figures for the posts created are as in Table A.2.(2)

Table A.2.

Posts created by computers

	1964	1972
Data Proc. Managers	1.1	1.3
Systems Analysts	3.7	5.4
Programmers	5.6	7.4
Machine Operators	19.1	20.1
Others	-	5.1

(1) Department of Employment. op.cit. p.28.

(2) Ministry of Labour, op.cit, p.20. Tables 3 & 4.

The figures for the 1972 study are calculated on a similar basis the surveys projections for 1972 being used.(1) These figures are all combined in Table 1. It would therefore seem that a saving of approximately 42 men per machine can be indentified.

It should be noted however, that if the transitional/permanent distinction is made and posts created in service bureaux and by manufacturers services are ignored, then a staff saving of 60 men per computer can be estimated.

2. Labour usage in capital goods construction

Census of Production data shows that in 1963,10,400 employees were involved in computer construction and in 1962 , 19,100. During 1963 290 machines were installed and 1126 during 1968. It is estimated that total home manufacture is 72% of the home market.(2) Thus there was sufficient labour to supply 810 machines in 1968 and 208 in 1963. This implies that labour per computer produced was 50 man years in 1963 and 24 man years in 1968.(3) However, to get a true estimate of labour requirements in computer manufacture we have to include labour in those sectors supplying computer manufacturers. In 1963,21% of sales revenue was spent on buying inputs from other sectors and in 1968, 43.6%.

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(1) Department of Employment, op.cit. pp. 27-8, Tables 14 & 15.

(2) In the Memorandum by the Ministry of Technology to the Select Committee, (U.K. Computer Industry, Vol. I, op.cit. p.355) the data indicates that 60% of the home market was supplied by U.K. production, and 35% of U.K. manufacture was exported in 1968. Exports were £47.6 m. and Imports £74.8 m. Thus the total home market must be £74.8 m x 2.5 = £187 m., and total home manufacture £47.6 m. x 2.857 = £136 m. Thus total home manufacture is 72% of the total home market. Of course these proportions may change over time but this seems a reasonably approximate way for correcting for the presence of foreign trade.

(3) These figures include R & D personell that should not really be included for these purposes but cannot be separated out.

Now, although some of the fall in labour requirements may be due to technological change and scale returns (the effect of which on the results are considered in the main text), it is felt reasonable to argue that between 1963 and 1968 the increase in 'bought in' inputs from 21 - 23.6% of sales caused the major fall in labour requirement. This could imply that 22% of sales bought in represents 26 man years of labour. Thus if we consider 1968 technology as involving 50 man years of labour it is equivalent to assuming 21% of sales spent buying in. This is of course a very approximate way to estimate labour inputs.

The alternative techniques replaces by computers involve mainly office machinery, although some logging and control equipment has been replaced. Census of Production data indicates that in office machinery manufacture, 30,000 men were employed in 1963 and 30,700 in 1968. The Computers in Offices survey estimates that office employment would have increased at almost 2½% p.a. without computers. If one assumes that each new employee would then have been equipped with the same machines as older employees, then over the five year period an increase in labour in machine manufacture of approximately 12% would have been required. On 1963 productivity rates this would have meant 34,188 employees in Office Machine manufacture in 1968. However, only 30,700 were employed, which implies that computerisation prevented the creation of 3,488 jobs. During the period 2,647 computers were installed thus an average of 1.5 jobs per computer were not created in this sector. The comments to be made on this are :

(a) any complication through home versus foreign construction has been ignored.

(b) the figures do not include labour input into the products supplied to this sector, either current or capital input. It is assumed that this will offset any purchases of the computer sector from outside that have not been covered by the above estimating procedure.

(c) the figures will be compared with the extra labour required for computer manufacture. Fortunately there is little reason to believe that any adjustment will be required for different productive lives of equipment.

(d) these figures do not include the logging and control equipment being replaced and make no allowance for productivity increases in office equipment manufacture or usage.

Because of these comments the figure of 1.5 is rounded to 2.0, which will also make calculations simpler.

Thus we can say that net increase in labour demand is 48 man years per computer constructed. It is assumed that computers take 2 years to build and office machines one, yielding labour demand of 25 and 23 man years in years -2 and -1 'computer profile time'.