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WORKING PAPER

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Foreword

This paper is one of the first research products of the newly established Computer Integrated Manufacturing (CIM) Project, of which Prof. Ayres is the leader. It addresses issues of occupation-by-sector data availability, international comparability, and suitability for use with formal I-O models. Methods of estimating labor substitutability by CIM are also discussed, along with some early estimates of the impact of robotics on employment. The paper was formally presented at a session of the American Economic Association meeting in New Orleans, December 30, 1986. As an IIASA working paper it will be available to collaborating researchers and institutions in other countries.

V. Kaftanov
Deputy Director

R.U. Ayres
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Computer Integrated Manufacturing and Employment: Methodological Problems of Estimating the Employment Effects of CIM Application on the Macroeconomic Level

1. Problem Statement

Unquestionably, some of the most important impacts of the advent of computer integrated manufacturing or CIM concern the labor force impacts. Relevant aspects of the problem include labor displacement, structural changes in the labor force, changes in work-content, and changes in the work environment. The importance of these problems is reflected in an immense number of papers and books (see, for example, Engelberger, 1980; Hunt & Hunt, 1983; Ayres & Miller, 1983; Ota, 1984; Haustein & Maier, 1981, 1985; Leontief & Duchin, 1986; and Kaya, 1986).

There is general agreement on the fact that on the micro-level the application of CIM is accompanied by direct labor displacement and changes in skill requirements. A fairly large number of semi-skilled operative jobs is being eliminated, though gradually. A far smaller number of highly skilled jobs is being created at the same time. There is also an agreement with regard to the fact that the current state of CIM application has not yet led to any significant changes in the employment level or employment structure (e.g. the qualification structure) at the level of a national economy. T. Vasko (1983) emphasized: "This is typical of major innovations: They begin to have a significant impact on certain branches even before macroeconomic indicators become responsive. Therefore it is difficult to prove any significant impact on (always aggregated) macroeconomic data."

Opinions about the medium and long-term employment impacts of CIM differ considerably. Some authors emphasize the problem of job replacement accompanied by higher unemployment. Other authors are of the opinion that the labor-saving effects of CIM application will lead to higher productivity and income, resulting in higher domestic demand (and improved export competitiveness) ultimately creating a net increase in total employment.

These different assessments of the employment effects of CIM applications are supported--among other things--by the use of different forecasting methods, different assumptions on the diffusion rates and the application potential of CIM and the expected productivity effects of this technology.

The subject of this paper is to analyze the advantages and disadvantages of the input-output approach for estimating the employment effects of CIM application and to discuss the main directions of investigations to these problems at IIASA.

2. Input-Output Analysis: An Approach for Estimating the Employment Impacts of CIM

Advantages and disadvantages of different methods for estimating the employment effects of technological changes such as CIM are discussed repeatedly in the literature (Brooks, 1985; Friedrich & Roenning, 1985; Informationstechnologie, 1980). In this connection Brooks characterized the Input-Output analysis as the approach, which "provides the most rigorous method for projecting employment effects of new technologies because it is capable of accommodating economy-wide effects arising out of the linkage among sectors and thus of tracing through the system-wide impacts of introduction of a particular technology."

The first attempt to use an input-output model in order to estimate economic impacts of microelectronic application was made by Fleissner et al. (1981) in Austria. W. Leontief (1982, pp. 161,163,164) commented in regard to this study: "Although current business publications, trade papers and the popular press abound with articles about "automation" and "robotics" and speculation on the economic impact of these developments, only the governmental and scientific agencies of Austria have produced a systematic assessment of the prospective consequences of the present revolution in labor saving technology in a modern industrial economy and society ... No comparable study has yet been completed for the U.S. economy ... The Austrian study presents the best model available for projections of conditions in the U.S. of 1990."

Leontief and Duchin (1986) subsequently published a study in which the impact of computer-based automation on employment is analyzed using an input-output model for the U.S. This model differs from that of Fleissner in three important ways:

a) In the Leontief model the vector of non-investment final demand is provided from outside the model. Fleissner et al. estimated the final demand with the help of an econometric model which is linked with a demographic and an input-output model.

b) While Fleissner et al. used a static input-output model, Leontief and Duchin developed a dynamic input-output model[1].

c) In the Fleissner model the sectoral labor forces are subdivided by sex and four formal educational levels, whereas Leontief/Duchin used a more detailed occupation-by-sector matrix (53 occupations).

One drawback of both models is that they do not reflect the feedback of the cost reduction achieved by CIM application to a possible demand increase resulting from lower prices of goods.

A study, in which the approach of Fleissner et al. was used was made by Mc Curdy (1985a, b). Howell (1986) used an input-output model, which is similar to the Leontief model, to calculate the relative industry and occupational effects of alternative levels of the use and production of industrial robots in the U.S.A.

As these examples suggest, the <u>main advantage</u> of the input-output approach consists in the consideration not only of the employment effects of CIM application in a certain sector, but also of the effects which are caused by CIM production and application in other sectors of the economy.

But one has to consider that with the help of input-output models not all important effects of CIM application can be estimated. Some of the <u>methodological limitations</u> which can be observed in the above mentioned studies should be mentioned:

a) In input-output models only attributes of flexible automation equipment can be considered that can be reflected in the parameters or the variables of the model, e.g. the technological coefficients, in the labor input coefficients or in the final demand sector. However, the question arises: in what way can the effects of the increased

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[1] Strictly speaking, it is quasi-static, since most of the time variation is introduced exogenously.

flexibility of CIM be reflected in the model? Vasko (1983, p.5) has noted: "There is no established way to measure the flexibility of the flexible systems."

b) In input-output models each technology represents an "average" technology of the corresponding (more or less aggregated) production process. An innovation like CIM causes exceptional effects which can not be adequately reflected in "average" technologies.

c) In what way can such effects as changed work-content, work environment, etc, which are conditioned by CIM application, be reflected in the model?

In the literature these (hardly quantifiable) effects are especially emphasized. As we have said elsewhere, it is important to emphasize--more than once if need be--that the societal importance of various issues may well be in inverse ratio to their quantifiability. (Ayres, 1986).

d) How can the employment effects of CIM application be "isolated"? The current industrial revolution is forced by a "cluster" of basic innovations which commonly have an influence on the employment development. Besides, the evolutionary development of labor skills and demand patterns is conditioned by structural and organizational factors as much as by technological ones.

e) Input-output tables (at least in the U.S.) are many years out of date. This is conditioned by the time and labor-intensive work required to process the necessary data. Fleissner et al. used in their study, which was published in 1981, the input-output tables from the years 1970 and 1976. Leontief/Duchin used tables from 1967, 1972, and 1977. This led to severe problems in parameter forecasting (see Friedrich, Roennig, 1985).

f) On the microeconomic level the effects of application of CIM are likely to be very high in comparison to the traditional technology. But these enormous effects on the microeconomic level will not immediately be "transferable" to the sectoral and the macroeconomic level to the same extent (see also Ayres & Miller, 1983)[2]. The effects on the sectoral and the

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[2] Haustein & Maier (1985) called this the "transformation problem" of the projected dynamical efficiency into a real push of the average efficiency.

macroeconomic level can be so low in some cases that they would lie within the error margin of the parameter estimation of the input-output model.

With regard to these methodological limitations one should be aware that any model reflects only a "facet" of reality. The impact of CIM has so many aspects that it is unlikely to be completely reflected by any input-output model. A number of other complementary approaches and models will be needed. Nevertheless, with regard to the estimation of the impacts of CIM on the level of employment, educational qualification and occupational structure of the labor force, input-output analysis is a powerful approach.

3. Computer Integrated Manufacturing and Employment: Directions of Research in the CIM Project at IIASA

Bearing in mind the background outlined above, our own investigation this far has been concentrated on the following three problems:

a) The development of an approach to estimate the impacts of CIM on employment by occupation;

b) The computation of detailed and internationally comparable labor matrices (occupation-by-sector matrices);

c) The linkage of the labor matrices to the related input-output models which are included in the existing INFORUM system (Almon, 1977).

Estimation of the Impacts of CIM Application on Labor Forces by Occupation

A preliminary remark is appropriate: In order to estimate the influence of technological progress on the occupational structure of employment, it is necessary to summarize the heterogenous diversity of working places into groups that are comparatively influenced by technological progress. For this purpose it is helpful to define similar tasks or occupations[*]. Tasks are generally more descriptive of the actual work-content

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[*] The difference between the terms task and occupation can be simply explained by the following example: The task "programming" may be done by people with different occupations. The occupation "programmer" is characterized by doing the task "programming" in the majority of one's working time.

of a job (Warnken, 1986). On the other hand the subdivision of the labor force by occupation has the advantage that it establishes a direct connection with educational planning.

Hence, in order to estimate the influence of the technological progress on the level and the structure of employment and to infer the consequences for education, it would be very useful to have data on the occupational composition by sectors and by tasks as well as the task composition by sectors. Such a detailed data basis is--to our knowledge--available only for the FRG (Figure 1). However relationships between tasks and occupations are likely to be reasonably similar in countries of a comparable level of economic development.

Task-by-sector matrices are available only for a few countries, but the occupation-by-sector matrices are available for many more countries.

The following indicators have to be considered to estimate the impact of CIM on employment-by-occupations.

- The fractional share of the workers in a certain occupation potentially affected by the application of a certain CIM technology (e.g. robotics or CAD);
- The fractional share of affected workers actually displaced;
- The resulting increase of labor productivity attributable to this technology.

Data about the replacement potential of certain CIM technologies by different occupations and sectors can best be determined on the basis of engineering analysis. An example of this approach follows. Detailed engineering studies for different countries are currently not available, but some information permitting estimates of this kind will be sought in the IIASA project.

Data on the number of machine tools in use, by category and by type of control, is collected every 5 years by the American Machinist (Mc Graw-Hill) for each metalworking sector (SIC 33-38). The 13th survey was published in 1983 and the 14th will appear in 1988.

In his PhD thesis S. Miller (1983) classified all machine tools into 4 categories, as shown in Table 1, below. A detailed allocation is given in Appendix 1. He also estimated the percentage of all machine tools in the U.S. that could, in principle, be operated by level I robots (roughly, 1982

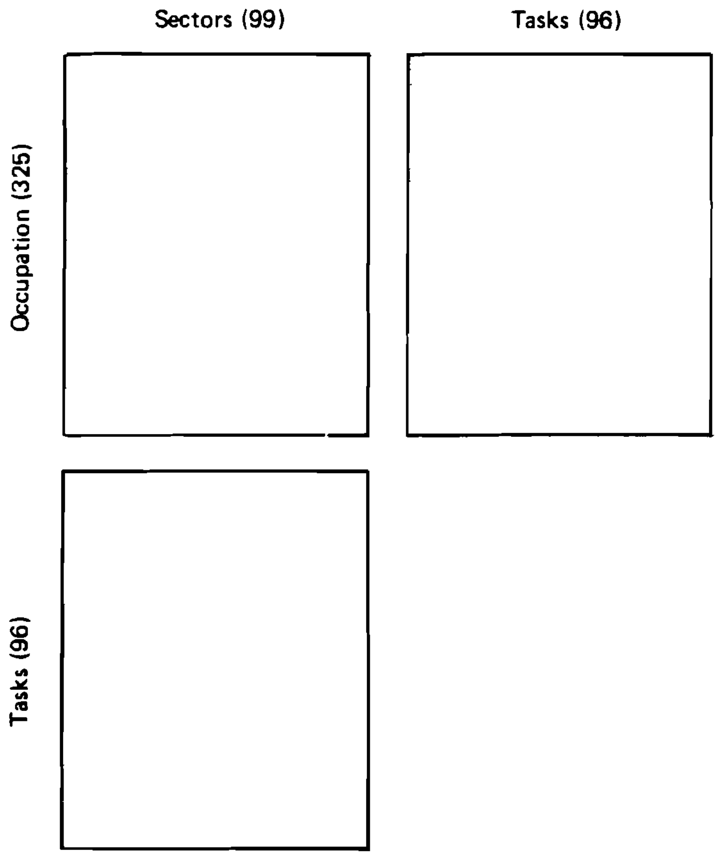


Figure 1. System of labor matrices in the FRG.

Table 1.

Low and High Estimates of the Distribution of Metalcutting Machine Tools By Category

Category	Percent of Machines (Low Estimate)	Percent of Machines High Estimate
Category 1 (Machines designed for low volume production)	39.4	68.2
Category 2 (Machines designed for fully automatic operation)	12.0	19.9
Category 3 (Machines designed for very large and/or heavy workpieces)	1.1	1.7
Category 4 (Machines designed for medium to large batch production)	9.4	46.7

technology) and by level II robots (roughly, 1990's technology), Table 2. Combining the results in graphic form yields the pie chart (Figure 2). This suggests that the upper limit for numerical control (and robotic operation) is probably around 48% of the existing machine tool population, which would also be about the upper limit of machine operator displacement. This compares well with an earlier industry survey--admittedly limited in scope--carried out at Carnegie-Mellon University (Ayres & Miller, 1983) which suggested that respondents thought that 39.5% of operatives could be replaced by a level II robot (but only 13.6% could be replaced by a level I robot).

The above results can be regarded as a crude sort of validation for the survey methodology. A far more far-ranging survey (of 474 respondents) was carried out in 1984 by the Japan Industrial Robot Association JIRA (JIRA, 1985). The JIRA study focussed on the number of workers replaceable by industrial robots by tasks and by sectors. Based on this, the potential labor displacement matrix for the whole Japanese manufacturing industry can be estimated. It must be noted that the JIRA survey covers only a small part of the Japanese industry, although it is much more comprehensive than the Ayres/Miller survey. JIRA results for Japan are summarized in Table 3 (columns 1,2). Assuming JIRA's substitutability data to be similar to the U.S. manufacturing industry, the potential for labor substitutability of the U.S. is also estimated (Table 3, columns 3,4). We finally compare the results with the estimates by Ayres & Miller (1983), in columns 5,6. Details of the procedure are given in Appendix 2.

Although the classification of occupations is rather different between the surveys of JIRA (1985) and Ayres & Miller (1983), it can be concluded that the results are basically consistent. It is noteworthy that the potential displacement ratio estimated from JIRA's survey is roughly within the range for level I and level II robots given by Ayres & Miller (1983).

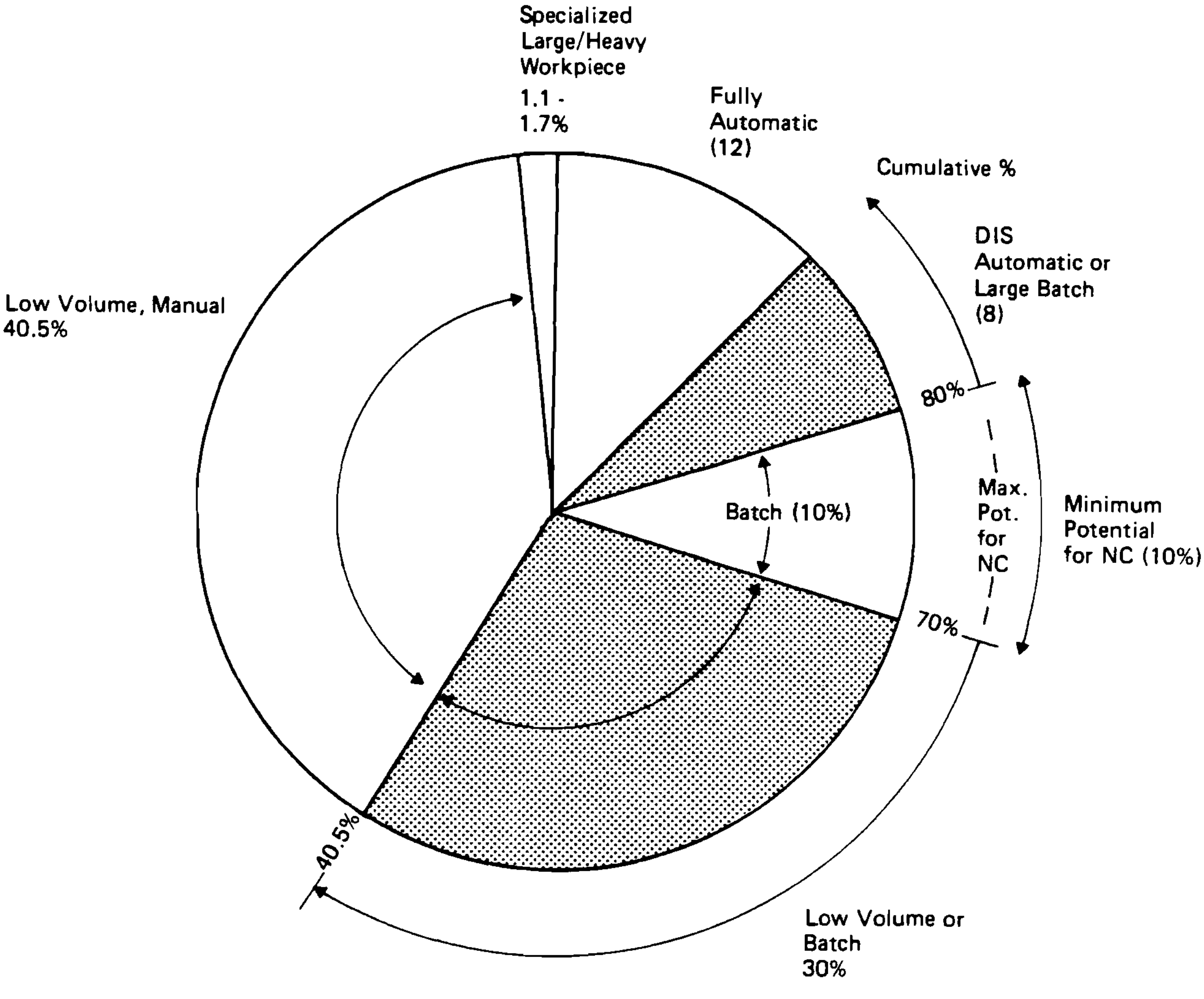
Another approach taken in the JIRA survey also deserves discussion. The 474 respondents were asked (in effect) how much they would be willing to pay in capital costs to reduce the total number of workers by one. This can be interpreted as the marginal capital value of a robot system per worker replaced. Data is presented in Figures 3,4 for various tasks in terms of

Table 2.

Estimates of the Percent of Metalcutting Machine Tools That Could be Operated by Level I and Level II robots

MACHINE TYPES ASSIGNED TO	Percent of All Machines in Metalworking Industries
Category 4 only	9.4
Categories 4 and 2	6.3
Subtotal	15.7 -- Max. for level I robot
Categories 4 and 1 and Categories 4 and 3	37.3
Total, Category 4 (exclusively and jointly)	46.7 -- Max. for level II robot

Machines Which Could be Operated by a Level I robot	9.4 - 15.7%
Machines Which Could be Operated by a Level II robot	46.7%



Min Potential for NC	10%
Max Potential for NC	48%
Min Potential for Automatic	12%
Max Potential for Automatic	20%
Min Potential for Manual	40.5%
Max Potential for Manual	70%

Figure 2. Classification of machine tools by use and control (based on Miller, 1973)

Table 3.

Comparison of Labor Displacement Estimation
in Metal Working Industry (in 1000 workers)
upper : potential displacement worker
middle:[total employment]
lower :(potential displacement ratio)

[I] ;Level I robot (non-intelligent robot)
[II];Level II robot (intelligent robot)

SIC33-38;primary metal, fabricated metal products, general machinery, electric machinery, transportation machinery and precision machinery
SIC34-37;fabricated metal products, general machinery, electric machinery and transportation machinery

	Japan (JIRA)		U.S. (a)		U.S. (b)			
	SIC34-37	SIC33-38	SIC34-37	SIC33-38	SIC34-37		SIC33-38	
					[I]	[II]	[I]	[II]
casting	14.9	17.7	7.9	10.5	1.1	2.8	3.7	9.3
	[41.8]	[75.5]	[35.9]	[46.5]	[7.0]		[31.8]	
	(35.6%)	(23.4%)	(22.0%)	(22.6%)	(15.7%)	(40.0%)	(11.6%)	(29.2%)
die casting	18.0	21.4	59.4	77.3	.4	1.0	2.0	4.7
	[28.5]	[40.7]	[154.5]	[174.6]	[6.5]		[11.7]	
	(63.2%)	(52.6%)	(38.4%)	(44.3%)	(6.2%)	(15.4%)	(17.1%)	(40.2%)
plastic forming	22.4	28.2	21.7	21.7	7.2	18.2	8.2	20.7
	[63.7]	[75.0]	[21.7]	[21.7]	[37.2]		[42.0]	
	(35.2%)	(37.6%)	(100%)	(100%)	(19.4%)	(48.9%)	(19.5%)	(49.3%)
heat treatment	23.0	27.4	14.5	18.1	2.8	11.1	6.2	23.0
	[113.0]	[166.3]	[56.5]	[78.2]	[21.3]		[42.9]	
	(20.4%)	(16.5%)	(25.7%)	(23.1%)	(13.1%)	(52.1%)	(14.5%)	(53.6%)
forging	11.2	14.0	4.3	4.9	1.2	5.3	1.5	7.0
	[22.2]	[54.3]	[16.8]	[17.6]	[7.5]		[10.0]	
	(50.5%)	(25.8%)	(25.6%)	(27.8%)	(16%)	(70.7%)	(15.0%)	(70.0%)
press & shearing	54.3	64.6	31.5	37.9	32.9	146.2	33.6	152.7
	[215.6]	[254.9]	[58.2]	[63.9]	[202.7]		[221.4]	
	(25.2%)	(25.3%)	(54.1%)	(59.3%)	(16.2%)	(72.1%)	(15.2%)	(69.0%)
welding	112.0	134.5	86.2	96.4	86.1	156.3	93.0	168.7
	[344.1]	[366.6]	[253.9]	[271.6]	[319.0]		[344.3]	
	(32.5%)	(36.7%)	(34.0%)	(35.5%)	(27.0%)	(49.0%)	(27.0%)	(49.0%)

Table 3. (continued)

	Japan (JIRA)		U.S. (a)		U.S. (b)			
	SIC34-37	SIC33-38	SIC34-37	SIC33-38	SIC34-37		SIC33-38	
					[I]	[II]	[I]	[II]
painting	64.9	77.2	18.4	22.2	32.7	49.1	34.6	51.8
	[180.9]	[211.2]	[60.2]	[66.5]	[74.4]		[78.5]	
	(35.9%)	(36.6%)	(30.6%)	(33.4%)	(44.0%)	(66.0%)	(44.1%)	(66.0%)
plating	25.6	30.5	11.2	14.2	19.8	50.3	16.4	57.1
	[82.2]	[112.2]	[51.8]	[55.8]	[61.3]		[66.1]	
	(31.1%)	(27.2%)	(21.6%)	(25.4%)	(32.3%)	(82.0%)	(24.8%)	(86.4%)
grinding & machining etc.	70.3	83.6	151.5	199.1	139.8	363.2	155.3	397.4
	[241.8]	[305.4]	[918.5]	[990.4]	[764.1]		[861.8]	
	(29.1%)	(27.4%)	(16.5%)	(20.1%)	(18.3%)	(47.5%)	(18.0%)	(46.1%)
assembly	87.0	102.0	297.6	338.5	118.3	354.8	131.9	395.6
	[372.2]	[431.3]	[1097.3]	[1230.3]	[1182.7]		[1318.8]	
	(23.4%)	(23.6%)	(27.1%)	(27.5%)	(10.0%)	(30.0%)	(10.0%)	(30.0%)
loading & packaging	69.4	82.6	103.0	134.3	10.7	28.1	14.1	37.0
	[237.1]	[305.2]	[338.8]	[412.1]	[73.6]		[95.8]	
	(29.3%)	(27.1%)	(30.4%)	(32.6%)	(14.5%)	(38.2%)	(14.7%)	(38.6%)
inspection	72.9	86.7	47.9	63.0	33.8	86.2	40.1	112.0
	[275.3]	[356.3]	[325.5]	[371.1]	[280.0]		[332.8]	
	(26.5%)	(24.3%)	(14.7%)	(17.0%)	(12.1%)	(30.8%)	(12.5%)	(33.7%)
subtotal	639.7	760.9	833.4	1016.4	486.8	1272.6	540.6	1437.0
	[2046.8]	[2562.2]	[3089.9]	[3800.0]	[2981.7]		[3382.1]	
	(31.3%)	(29.7%)	(27.0%)	(26.7%)	(16.3%)	(42.7%)	(16.0%)	(42.5%)
others	98.8	121.0	645.5	848.4	16.7	43.5	36.2	58.6
	[103.4]	[164.5]	[2070.4]	[2411.0]	[154.6]		[258.7]	
	(95.6%)	(73.6%)	(31.2%)	(35.2%)	(10.8%)	(28.1%)	(14.0%)	(22.7%)
total	738.5	881.9	1478.9	1864.8	503.2	1316.8	576.8	1495.6
	[2322.1]	[2918.5]	[5160.3]	[6211.0]	[3136.3]		[3640.8]	
	(31.8%)	(30.2%)	(28.7%)	(30.0%)	(16.0%)	(42.0%)	(15.8%)	(41.1%)

(a) Based on the JIRA Substitutability data

(b) Based on Ayres-Miller (1983)

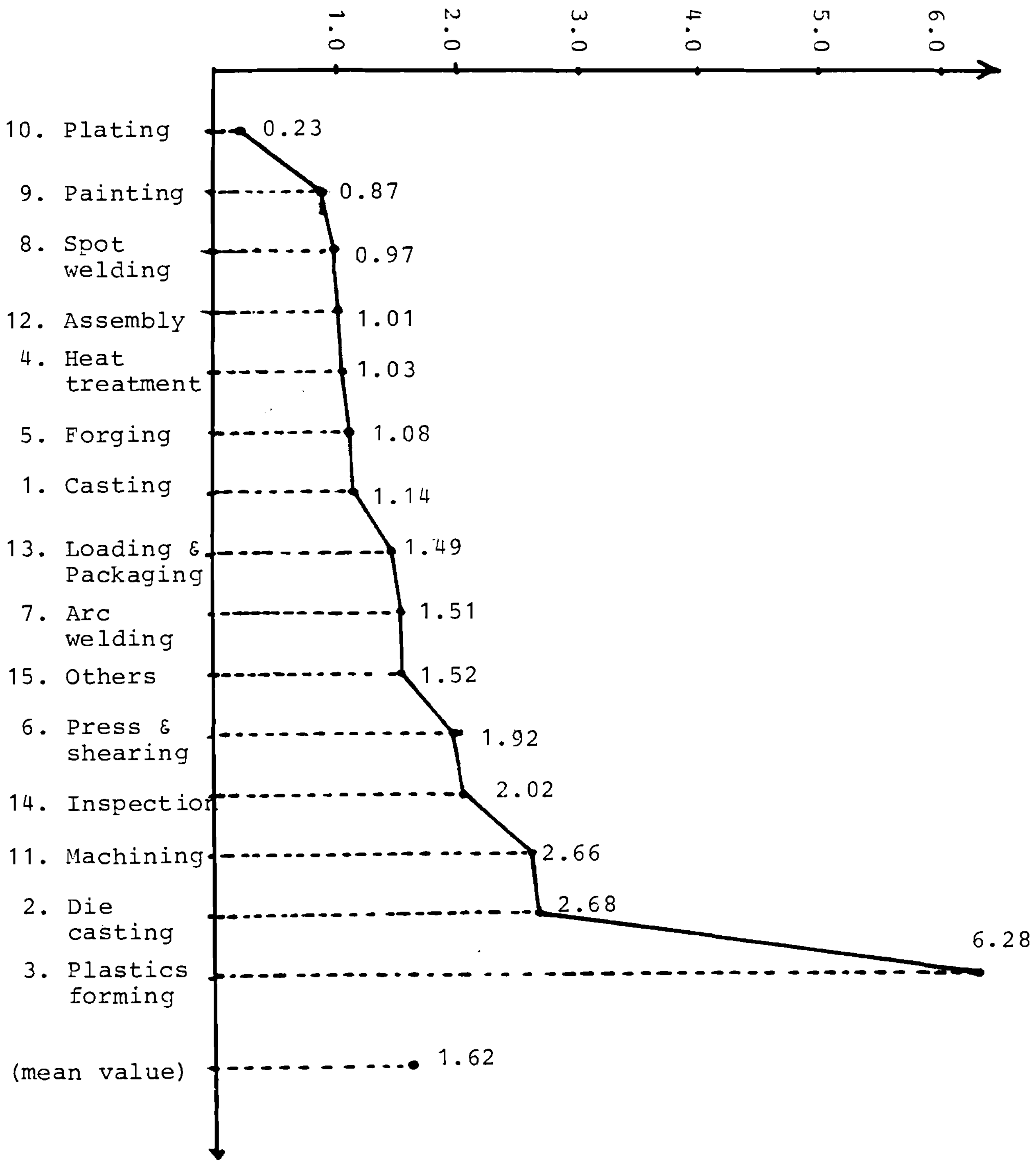


Figure 3. Entrepreneur's willingness to invest to replace one worker
(average robot price excl. system cost).

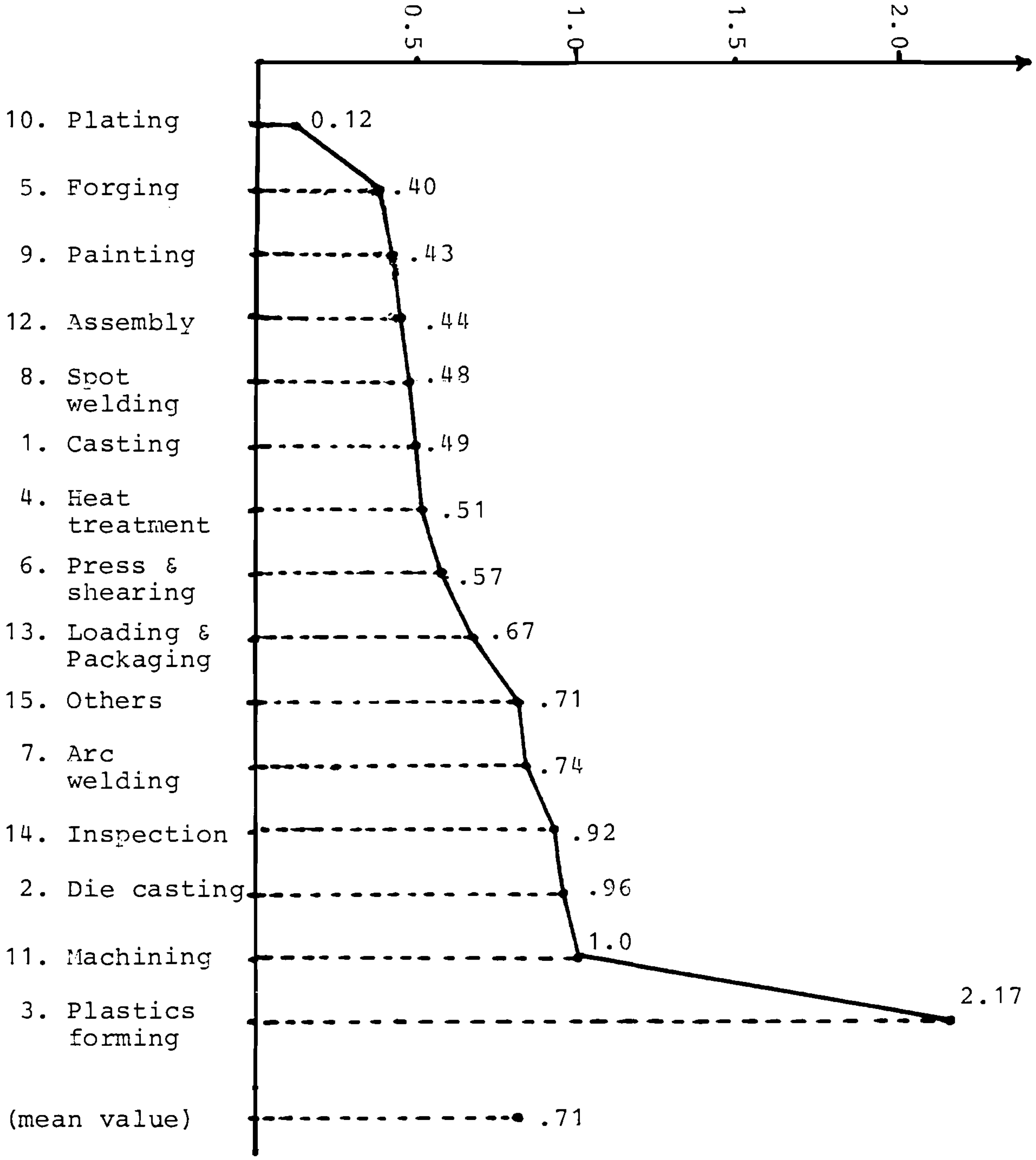


Figure 4. Enrepreneur's willingness to invest to replace one worker
(average robot price incl. system cost).

ratios between the average marginal capital value of a single replaced worker (as perceived by managers or entrepreneurs) and the average cost of a robot. It is noteworthy that for most tasks the ratio is greater than unity, implying that ceteris paribus robots were economically justified in Japan (1984) if they could displace only a single worker. In most cases, the observed displacement ratio is closer to one worker per shift, or nearer to 2 workers per robot.

It is already clear that not all workers are substitutable, even for the most routine tasks. Thus, the marginal willingness-to-pay data presented in Figure 4 might be regarded also as a measure of distance from equilibrium. If all justifiable robots were actually in place, the theoretical ratio should be 0.5± 0.1. A high ratio suggests that the potential for substitution is much higher than the current level of penetration. Conversely, a low ratio suggests a very low potential for substitution.

This procedure allows one to get an "impression" of the range of labor substitutability due to CIM. This procedure is not necessary if detailed engineering surveys about the potential labor substitutability by sectors and occupations becomes available and more careful computations can be made.

The Elaboration of Detailed Internationally Comparable Labor Matrices

Application of the input-output approach for estimating the employment effcts of CIM application requires the reconciliation of detailed occupation-by-sector matrices for different countries.

Only two prior studies on internationally comparable labor matrices are known to us. In 1969/70 the OECD published a set of highly aggregated labor matrices for 53 countries. The most sophisticated study was carried out at the World Bank by Zymelman (1980) which analyzed matrices with 120 occupations and 58 sectors for 26 countries around the year 1970/71. Zymelman's work has not been updated. The problems of constructing internationally comparable labor matrices are discussed in Appendix 3.

The main objectives of this task are the following:

a) The creation of a data base for the computation of the direct employment displacement effects of CIM by methods discussed above. (The substitutional potential for a given CIM technology must be referenced to a standard occupational and sector classification.)

b) The investigation of possibilities for synthesizing labor matrices which are not available from primary sources (e.g. census or micro census).

It must be recalled that labor matrices are available only for a limited number of countries.

If one can find recognizable similarities in industry/occupation patterns between different countries then it is possible to extrapoate countries for which labor matrices are not available. Zymelman (1985) emphasized that there is a plausible relation between the labor productivities of industries (sectors) and their occupational structures. Two approaches can be used to synthesize occupational structures from international data: judgmental (comparative) and statistical. In the first method, relationships between occupation and productivity are assumed and used to infer the patter for an unkown case from patterns that are known. In the statistical approach, average coefficients for occupation by sector can be determined by cross-sectoral analysis. The first method is preferable, but requires much more analysis. Unquestionably, the work of Zymelman represents the current state-of-the-art in this field. Our intention is to use the same nomenclature for sectors and occupations as Zymelman to obtain a consistent series covering 3 decades.

The Incorporation of the Labor Matrices in the INFORUM System

In the literature one can find conjectures that the broad application of CIM will lead to important shifts in the international division of labor (see e.g. Sadler, 1981). This could be caused, for instance, by the increasing competitiveness of CIM users. It is widely assumed that this could lead to negation of the lost advantages of so-called low-wage countries because in the developed countries highly-paid semi-skilled workers can be largely replaced by CIM. If so, this could result in important cost reductions. In consequence, one might foresee an increasing gap between developed and developing countries.

Confirmation of such hypotheses requires the extension of economic analysis to include international trade. Perhaps the only suitable instrument available today is the so-called INFORUM system which was designed at the University of Maryland under the leadership of Professor Clopper Almon (Almon, 1979; Nyhus & Almon, 1980). An important part of this system is the linkage of a number of national input-output models for key trading countries using special trade models.

Our objective of the present CIM activity at IIASA consists partly in the linkage of the occupation-by-sector mmatrices with the corresponding national input-output models now included in the INFORUM system. Unfortunately, not all national input-output models are included in the INFORUM system, and among these are only developed countries. Hence, the hypothesis of whether the CIM application could lead to an increasing gap between developing and developed countries cannot be verified with the help of this model alone.

Conclusions

The investigations of the employment impacts of CIM application are still in the initial stage at IIASA. The chosen approach, namely the incorporation of the labor matrices in the INFORUM model, might be a new departure in the investigation of employment impacts of CIM. One precondition for estimating the labor impacts of CIM application is a reconciliation and synthesis of detailed labor matrices. The paucity of available studies on this subject is an indication of the severity of the problems of data collection and interpretation.

With regard to potential labor substitutability by CIM applications in the different sectors and occupations there exits a deficit in established knowledge. While the simple procedure described above allows one to estimate the range of labor substitution potential, a truly satisfactory computation requires detailed data from engineering studies.

The importance of the elaboration of detailed labor matrices is not limited to the estimation of the employment impacts of CIM or other high technologies. Rather, we expect that the investigation about the occupational structure by industries can contribute to answering further questions in labor economics, e.g.

a) What are the determinants of the occupational structure?

b) How can these determinants be quantified?

c) Can functional relations be given between the explanatory factors and the occupational structure?

d) What possibilities exist to prove the estimated functional relations?

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Appendix 1

Categories of Metalcutting Machine Tools In the American Machinist 12 th Inventory

TYPES OF METALCUTTING MACHINES IN AMERICAN MACHINIST 12th INVENTORY	CATEGORY	
	NOT NC CONTROLLED	NC CONTROLLED
TURNING MACHINES		
Bench	1	4
Engine and toolroom < 8 in swing	1	4
Engine and toolroom 9 to 16 in swing	1	4
Engine and toolroom 17 to 23 in swing	1	4
Engine and toolroom 24 in swing and over	1	4
Tracer lathe	1	4
Turret lathe; ram type	1,4	4
Turret lathe; saddle type	1,4	4
Auto chuckg vert & horiz; sgl spindl	2,4	2,4
Auto chuckg vert & horiz; multi-spindl	2,4	2,4
Automatic between centers chucking	4	4
Automatic bar (screw) mach; sgl-spndl	2,4	2,4
Automatic bar mach; mult-spndl	2,4	2,4
Vert turn & boring mills (VTL, VBM)	3	3
Other, incl, forin, axle, spin, shell	1,4	4
BORING		
Hor. bore,drl,mil (bar mach); tabl&plnr type	1	4
Hor bore,drl, mile (bar mach); floor type	1	4
Precision, horiz and vert	1	4
Jig bore, horiz and vert	1	4
other (not boring lathes)	1	4
DRILLING		
Sensitive (hand feed),bench	1	4
Sensitive (hand feed), floor & pedestal	1	4
Upright:single-spindle	1,4	4
Upright: gang	4	4
Upright: turret, not NC	1,4	-
Radial	1	4
Multi-spdl cluster (adj and fxd ctr)	2,4	2,4
deep hole (incl gun drill)	1,2,4	3,4
other (not unit head & way)	1,4	4
MILLING		
Bench type (hand or power feed)	1	4
Hand	1	4
Ver ram type (swivel head & turret)	1	4
Gen prpse, knee or bed:hor (pin, univ & ram)	1,4	4
Gen prpse, knee or bed: vert	1,4	4
Manufacturing, knee or bed	1,4	4
Planer type	1,3	3,4
Profiling & duplct (incl die,skin,spar)	4	4

Thread millers	2,4	2,4
Others (incl spline,router,engraving)	1	4
TAPPING MACHINES	4	4
THREADING MACHINES	2,4	2,4
MULTI-FUNCTION NC MACHINES (MACHINING CENTERS)		
drill-mill-bore,manual tool chg,vert&hor	4	4
drill-mill-bore,indexing turret	4	4
drill-mill-bore,auto tool chg;vert	4	4
drill-mill-bore,auto tool chg;horiz	4	4
SPECIAL WAY TYPE & TRANSFER MACHINES		
Sgl-statn (several operations on one part)	2	2
Multi-station:rotary transfer	2	2
Multi-station:in line transfer	2	2
BROACHING MACHINES		
Internal	4	4
Surface & other	4	4
PLANING MACHINES		
Double column	1,3	3,4
Openside and other	1,3	3,4
SHAPING MACHINES (not gear)		
Horizontal	1	4
Vert (slotters & keyseaters)	1	4
CUTOFF & SAWING MACHINES		
Hacksaw	2	2
Circular saw (cold)	2	2
Abrasive wheel	2	2
Bandsaw	2	2
Contour sawing & filing	1	4
Other (incl friction)	2	2
GRINDING MACHINES		
External;plain centertype	1,4	4
External;univ centertype	1,4	4
External; centerless (incl shoe type)	4	4
External; chucking	1,4	4
Internal; (chucking, ctrless shoe type)	1,4	4
Surface; rotary table, vert & horiz	1,4	4
Surface; reciprocating, horiz, manual	1	4
Surface; recipr, vert, horiz, power	1	4
Disk grinders, not hand held	1	4
Abrasive belt (exclu polishing)	1,4	4
Contour (profile)	4	4
Thread grinders	4	4
Tool & cutter	1	4
Bench, floor & snag	1,4	4
Other (incl jig)	1	4
HONING MACHINES		
Internal (incl combn bore-hone)	1,4	4
External	1,4	4
LAPPING MACHINES		

Flat surface	1	1
Cylindrical	1	1
Other (incl combn hone-lap)	1	1
POLISHING AND BUFFING MACHINES		
Polishing stands (bench & floor)	1	
Abrasive-belt, disk, drum (not grind)	4	
Other (incl spd lathes & multi-stn type)	2	2
GEAR CUTTING & FINISHING MACHINES		
Gear hobbers	2	2
Gear shapers	2	2
Bevel-gear cutters (incl planer type)	2	2
Gear-tooth finish (grind, lab, shave, etc)	2	2
Other Gear Cutting and Finishing	2	2
ELECTRICAL MACHINING UNITS		
Electrical discharge machines (EDM) ·	2	2
Electro-chemical machines (ECM)	2	2
Electrolytic grinders (ECG or ELG)	2	2

Automatic assembly machines and "other" metalcutting machines are omitted.

Appendix.2

Procedure for the estimation of potential labor substitution in Japan and U.S

The objective is to estimate the potential labor substitutability in U.S and Japan attributableto CIM. In case of Japan, JIRA(1985) has surveyed 474 companies and reported the ratio between potential substitutable workers by industrial robots and existing process workers by task and by industry sectors. Based on this, the potential labor replacement matrix for Japanese manufacturing industry which contains tasks in the columns and industry sectors in the rows can be estimated, as shown below.

Unfortunately, a labor matrix which contains both industry sector and tasks is not avaialble for the U.S.A. We can compare only the occupation-by-sector matrix for the U.S.A with that for Japan. To compound the difficulty, conversion tables between the national occupational classification systems for U.S and Japan to ISCO are not currently available. This makes difficult to achieve comparability.

In the following, a first tentative estimate of potential labor substitutability in the U.S is described.

A).Aggregate the occupational labor matrix for the U.S into the nearest classification to that of Japan and then equate it to the task labor matrix. Here, this procedure is employed. The result is shown in Figure A-1.

B).Aggregate Japanese occupation-by-industry labor matrix into the same classification as JIRA's task-by-industry labor matrix, say A_J. Hereafter, this aggregated occupation-by-industry labor matrix is denoted by B_J.

Let X_J denote the distribution of occupation among tasks, that is, conversion matrix from B_J to A_J. Namely,

$$A_J=B_JX_J \quad . \qquad (1)$$

$$X_J=B_J^{(-)}A_J \quad , \qquad (2)$$

where it is needed that generalized inverse matrix of B_J, namely

$$B_J^{(-)}=B_J^T(B_JB_J^T)^- \qquad (3)$$

exists.

C)Aggregate U.S occupation-by-industry labor matrix to a level similar to that of Japan. This aggregated matrix is denoted by $B_{U.S.}$

Under the assumption that the conversion matrice of Japan and U.S are same, we can calculate task-by-industry labor matrix of U.S., say $A_{U.S.}$

$$A_{U.S}=B_{U.S}X_J \qquad (4)$$

Next, let us describe the contents of applicable data in JIRA's report and the procedure in order to estimate the potential labor displacement of whole manufacturing industry.

LSsct(i)=potential labor substitutability by sector

LSjob(j)=potential labor substitutability by job type

Rjb(i,j)=respondence whether the factory has job step i or not (JIRA) by sector and job type, where i;industry sector and j;job type respectively.

DSBwk(i,k,l)=distribution of full time production workers, part time production workers and non-production workers by sector (JIRA), where i;industry sector, k;type of worker, l;job type(1:total, 2:production worker, 3:ratio (2/1))

LBM(i):number of workers by industry (MITI ; whole manufacturing industry)

The estimation procedure is as follows:

[A].estimation of total production worker, say PRwk(i), by industry

$$PRwk(i)=LBM(i)\cdot DSBwk(i,3,3) \qquad (5)$$

[B].distribution of production workers by industry sector and job type ; WRKR(i,j) (which corresponds to A_{j} described above.)

$$WRKR(i,j)=PRwk(i)\cdot Rjb(i,j)/\sum_{j=1}^{M} Rjb(i,j) \;. \qquad (6)$$

where M denotes total job type.

·One problem of the above estimation is

$$PRwk(total)\cdot Rjb(total,j)/\sum_{j=1}^{M} Rjb(total,j) \neq \sum_{i=1}^{N} WRKR(i,j). \qquad (7)$$

Here, the right hand side value is employed as WRKR(total,j).

·If appropriate task-by-industry labor matrix data is available, this step is not needed.

·WRKR(i,j) gives an upper limit of substitutable worker. (For example, the number of forging workers in the food industry is 0.)

[C].estimation of substitutable worker by sector, say SWsct(i), and by job type, say SWjob(j)

$$SWsct(i)=PRwk(i)\cdot LSsct(i) \qquad (8)$$

$$SWjob(j)=WRKR(total,j)\cdot LSjob(j) \qquad (9)$$

[D].estimation of substitutable worker by sector and job type, say SBST(i,j)

SBST(i,j) should satisfy the following constraints.

$$\sum_{i=1}^{N} SBST(i,j)=SBjob(j) \quad , \quad \sum_{j=1}^{M} SBST(i,j)=SBsct(i) \qquad (10)$$

and

$$0\leqq SBST(i,j)\leqq WRKR(i,j) \qquad (11)$$

Because of constraint (11), usual estimated value

$$\overline{SBST}(i,j)=SBsct(i)\cdot SBjob(j)/\sum_{i=1}^{N} SBsct(i) \qquad (12)$$

based on the assumption of independent distribution between SBsct(i) and SBjob(j) should be modified. Here the following procedure was employed.

$$\text{initial value} \quad SBST_0(i,j)=\overline{SBST}(i,j) \qquad (13)$$

The next step is to modify infeasible terms on job type.

```
if $SBST_k(i,j)>WRKR(i,j)$ then set $SBST_{k+1}(i,j)=WRKR(i,j)$
                               else $ROOM=ROOM+SBST_k(i,j)$
                               and  set $SBST_{k+1}(i,j)=SBST_k(i,j)$     (14)
```

Next, calculate row-wise error of $SBST_{k+1}(i,j)$.

$$ERR= SBsct(i)-\sum_{j=1}^{M} SBST_{k+1}(i,j) \qquad (15)$$

Next, distribute error term ERR on $SBST_{k+1}(i,j)<WRKR(i,j)$.

if $SBST_{k+1}(i,j)<WRKR(i,j)$ then $SBST_{k+1}(i,j)=SBST_k(i,j)\cdot(1+ERR/ROOM)$ (16)

Next modify the infeasible terms on industry sector (similar to the procedure (14) to (16))

Next, if maximum value of $|ERR/ROOM|$ is less than ε then end.

Finally, set $k=k+1$ and go to equation (14).

In practice, the above procedure converges after five iterations.

number of production process workers (in 1000) : whole industry

	1:casting	2:die cast -ing	3:plastics - forming	4:heat -treatment	5:forging	6:press & -shearing	7:arc weld -ing	8:spot wel -ding	9:painting	10:gilding
food & textile	1.15	0	4.97	41.53	0	53.57	0	0	6.06	0
wood & paper	.188	1.256	0	7.593	0	23.85	2.76	.59	21.9	0
chemistry	0	0	0	4.12	0	0	4.85	0	6.87	0
rubber & cement	0	16.6	165.42	18.61	.13	7.88	6.58	0	16.3	.912
iron & steel	9.68	15.98	0	21.37	.83	4.32	11.98	2.29	1.98	2.4
non-ferrous metals	23.43	11.11	0	23.49	.42	3.5	2.08	.9	1.41	1.16
metal products	3.48	34.99	0	9.69	5.7	31.34	21.77	50.19	13.85	31.35
general machinery	3.86	60.99	0	8.23	1.66	9.74	28.19	49.9	8.65	2.5
electric machinery	3.52	19.57	16.94	7.03	1.31	7.92	6.77	14.63	10.13	13.79
car & motorcycle	.81	15.27	3.17	5.19	6.97	3.46	19.04	21.35	8.97	1
other transportatio	.774	12.52	1.57	2.89	.75	2.26	31.82	7.25	17.21	2.03
precision machinery	.94	4.16	0	.32	0	1.35	2.83	.59	4.3	1.26
others	1.77	2.66	11.22	.96	0	156.57	2.9	.61	13.79	1.77
total	49.6	195.11	203.29	151.01	17.76	305.75	141.58	148.21	131.47	58.16

	11:grinding	12:Light -assembly	13:heavy -assembly	14:Loading	15:inspec -tion	16:others	17:total
food & textile	84.79	0	0	420.83	101.06	2149.44	2863.4
wood & paper	64.81	0	0	211.9	28.44	653.96	1017.24
chemistry	50.09	0	0	121.85	20	447.34	655.118
rubber & cement	86.27	0	0	167.7	58.48	508.51	1053.4
iron & steel	34.31	0	4.3	48.91	15.9	212.28	386.5
non-ferrous metals	46.04	0	12.8	27.32	13.67	488.71	656.03
metal products	246.77	3.93	0	112.16	43.89	472.02	1081.13
general machinery	353.46	108.36	155.53	58.23	67.81	333.76	1250.88
electric machinery	96.98	221.18	331.03	83.34	116.76	344.76	1295.55
car & motorcycle	95.3	22.3	147.6	44.5	45.86	200.9	641.7
other transportatio	80.22	56.79	37.78	13.29	37.5	230.32	534.99
precision machinery	37.31	67.11	61.6	24.32	29.74	128.31	364.14
others	44.74	20.61	23.89	139.44	17.57	625.19	1063.56
total	1321.09	500.28	774.54	1473.8	596.68	6797.07	12865.4

Figure A-1. U.S Aggregated Occupational Labor Matrix in 1984 estimated potential substitutable workers (in 1000) by sector

	1:casting	2:die cast -ing	3:plastics - forming	4:heat -treatment	5:forging	6:press & -shearing	7:arc weld -ing	8:spot wel -ding	9:painting	10:gilding
food & textile	1.2	0	5	11.8	0	28.7	0	0	6.1	0
wood & paper	.2	1.3	0	4.1	0	10.1	2.8	.6	5.3	0
chemistry	0	0	0	3.3	0	0	4.9	0	4.2	0
rubber & cement	0	15.6	36.6	3.8	.1	7.9	6.6	0	4.9	.9
iron & steel	.4	2.6	0	.6	.2	1.5	1.5	2.3	.8	.6
non-ferrous metals	1.5	11.1	0	2.7	.4	3.5	2.1	.9	1.4	1.2
metal products	2.4	17.3	0	4.2	1.3	10.3	9.9	15.7	5.4	4.1
general machinery	1.8	12.6	0	3.1	.9	7.5	7.2	11.5	3.9	2.5
electric machinery	2.1	15.1	16.9	3.7	1.1	7.9	6.8	13.8	4.7	3.6
car & motorcycle	.8	8.5	3.2	2.1	.6	3.5	4.8	7.7	2.6	1
other transportatio	.8	5.9	1.6	1.4	.4	2.3	3.4	5.4	1.8	1.4
precision machinery	.7	4.2	0	.3	0	1.4	2.8	.6	1.6	1.2
others	1.8	2.7	11.2	1	0	12.7	2.9	.6	6.7	1.8
total	13.6	96.6	75.6	42	5.1	96.6	55.4	59	49.4	18.1

	11:grinding	12:Light -assembly	13:heavy -assembly	14:Loading	15:inspec -tion	16:others	17:total
food & textile	84.8	0	0	81.2	39	525.8	796
wood & paper	43.3	0	0	28.5	13.7	184.7	299.1
chemistry	34.1	0	0	22.5	10.8	145.5	228.6
rubber & cement	39.7	0	0	26.2	12.6	169.5	327.6
iron & steel	6.6	0	4.3	4.3	2.1	28.1	56.8
non-ferrous metals	28.1	0	12.8	18.5	8.9	119.7	215.8
metal products	44.1	3.9	0	29	13.9	188	354.6
general machinery	32.1	54.1	38	21.1	10.2	136.9	347.7
electric machinery	38.6	65	45.6	25.4	12.2	164.5	432.7
car & motorcycle	21.6	22.3	25.5	14.2	6.8	91.9	220.1
other transportatio	15.1	25.4	17.8	13.3	4.8	64.2	166.9
precision machinery	12.9	21.8	15.3	8.5	4.1	55.1	132.2
others	44.7	20.6	23.9	36	17.6	233.1	424.4
total	443.9	212.6	182.8	328.7	156.3	2107.1	4194.1

Figure A-2. U.S Potential Substitutable Workers estimated potential substitution rate (%)

	1:casting	2:die casting	3:plastics - forming	4:heat -treatment	5:forging	6:press & -shearing	7:arc welding	8:spot welding	9:painting	10:gilding
food & textile	100	0	100	28.4	0	53.6	0	0	100	0
wood & paper	100	100	0	54.5	0	42.3	100	100	24.3	0
chemistry	0	0	0	79.1	0	0	100	0	61	0
rubber & cement	0	93.9	22.2	20.4	100	100	100	0	29.9	100
iron & steel	3.8	16.2	0	3	23.1	35.6	12.3	100	40.9	25.3
non-ferrous metals	6.6	100	0	11.4	100	100	100	100	100	100
metal products	69.8	49.4	0	43.4	22.5	32.7	45.3	31.4	39.1	13
general machinery	45.8	20.6	0	37.2	56.2	76.7	25.5	23	45.5	100
electric machinery	60.4	77.3	100	52.4	85.6	100	100	94.2	46.7	25.8
car & motorcycle	100	55.4	100	39.7	9	100	25.4	36.1	29.5	100
other transportatio	100	47.1	100	49.7	58.3	100	10.6	74.2	10.7	68.3
precision machinery	75.8	100	0	100	0	100	100	100	36.9	94.5
others	100	100	100	100	0	8.1	100	100	48.7	100
total	27.4	49.5	37.2	27.8	28.9	31.6	39.1	39.8	37.6	31.1

	11:grinding	12:light -assembly	13:heavy -assembly	14:loading	15:inspection	16:others	17:total
food & textile	100	0	0	19.3	38.6	24.5	27.8
wood & paper	66.8	0	0	13.5	48.2	28.2	29.4
chemistry	68.1	0	0	18.5	54	32.5	34.9
rubber & cement	46.1	0	0	15.6	21.5	33.3	31.1
iron & steel	19.2	0	100	8.9	13.1	13.3	14.7
non-ferrous metals	61	0	100	67.7	65	24.5	32.9
metal products	17.9	100	0	25.9	31.8	39.8	32.8
general machinery	9.1	49.9	24.4	36.3	15	41	27.8
electric machinery	39.8	29.4	13.8	30.5	10.5	47.7	33.4
car & motorcycle	22.6	100	17.3	31.9	14.9	45.8	34.3
other transportatio	18.8	44.7	47.1	100	12.7	27.9	31.2
precision machinery	34.6	32.5	24.8	35	13.8	43	36.3
others	100	100	100	25.8	100	37.3	39.9
total	33.6	42.5	23.6	22.3	26.2	31	32.6

Figure A-3. U.S the Percentage of Potential Substitutablity number of production process workers (in 1000) : whole industry

	1:casting	2:die cast -ing	3:plastics - forming	4:heat -treatment	5:forging	6:press & -shearing	7:arc weld -ing	8:spot wel -ding	9:painting	10:gilding
food & textile	0	0	34.6	34.6	0	0	0	0	0	0
wood & paper	0	15.6	0	15.6	0	31.2	15.6	31.2	31.2	15.6
chemistry	0	0	9.7	0	0	0	0	0	4.9	0
rubber & cement	0	0	75.9	10.8	0	10.8	7.2	0	50.6	7.2
iron & steel	18.1	2.6	2.6	38.7	28.4	20.6	10.3	2.6	15.5	18.1
non-ferrous metals	13.5	5.4	4.5	6.3	2.7	7.2	2.7	1.8	5.4	3.6
metal products	6.6	5	3.3	34.9	5	59.8	43.2	31.6	38.2	23.3
general machinery	13.7	4.6	3	30.5	9.1	45.7	71.6	27.4	61	9.1
electric machinery	11.3	8.4	42.2	22.5	0	67.6	46.5	40.8	47.9	35.2
car & motorcycle	8.2	9.8	13.1	19.6	7.4	34.4	31.1	34.4	23.7	13.9
other transportatio	2	.7	2	5.4	.7	8.1	10.1	7.4	10.1	.7
precision machinery	2.1	4.2	4.2	8.3	1	11.5	6.3	9.4	9.4	8.3
others	8.7	8.7	32.6	30.4	2.2	43.5	58.7	30.4	58.7	30.4
total	84.2	65	227.9	257.8	56.5	340.5	303.3	217	356.6	165.5

	11:grinding	12:light -assembly	13:heavy -assembly	14:loading	15:inspec -tion	16:others	17:total
food & textile	0	34.6	34.6	415.8	277.2	658.4	1490
wood & paper	31.2	15.6	31.2	109.2	62.4	156	561.4
chemistry	4.9	9.7	14.6	48.6	38.9	72.9	204.2
rubber & cement	21.7	36.2	3.6	72.3	101.3	61.5	434
iron & steel	36.1	2.6	7.7	36.1	43.9	36.1	319.9
non-ferrous metals	10.8	5.4	2.7	15.3	16.2	13.5	117
metal products	54.9	36.6	24.9	68.2	61.5	23.3	520.3
general machinery	83.8	45.7	62.5	59.4	74.7	21.3	623.4
electric machinery	64.8	94.3	52.1	67.6	91.5	33.8	726.4
car & motorcycle	30.3	24.6	18	31.1	36.8	15.6	352
other transportatio	8.1	5.4	8.1	10.8	10.8	9.5	100.1
precision machinery	16.7	29.2	11.5	16.7	20.9	11.5	159.5
others	67.4	58.7	52.2	67.4	73.9	63	686.9
total	430.6	398.6	323.8	1018.5	909.9	1176.3	6295

Figure B-1. Japan Aggregated Occupational Labor Matrix in 1984 estimated potential substitutable workers (in 1000) by sector

	1:casting	2:die cast -ing	3:plastics - forming	4:heat -treatment	5:forging	6:press & -shearing	7:arc weld -ing	8:spot wel -ding	9:painting	10:gilding
food & textile	0	0	34.1	25.8	0	0	0	0	0	0
wood & paper	0	4.2	0	5.3	0	12.6	14.5	11.4	15	6
chemistry	0	0	5	0	0	0	0	0	4.9	0
rubber & cement	0	0	6.4	4.9	0	10.8	7.2	0	13.7	5.5
iron & steel	.9	1.1	1.9	1.5	1	3.4	4	2.6	4.1	1.6
non-ferrous metals	.8	.9	1.6	1.2	.8	2.8	2.7	1.8	3.3	1.3
metal products	3.4	4.2	3.3	5.3	3.8	12.6	14.5	11.4	15	6
general machinery	3.6	4.3	3	5.5	4	13	15	11.8	15.5	6.2
electric machinery	4.9	5.9	10	7.6	0	17.8	20.6	16.1	21.3	8.5
car & motorcycle	2.4	2.9	4.9	3.7	2.7	8.7	10.1	7.9	10.4	4.2
other transportatio	.6	.7	1.2	.9	.7	2.2	2.6	2	2.7	.7
precision machinery	1.1	1.4	2.3	1.7	1	4.1	4.7	3.7	4.9	2
others	5.3	6.5	11	8.3	2.2	19.5	22.5	17.6	23.3	9.3
total	23.1	32.1	84.8	71.7	16.3	107.6	118.6	86.4	134.1	51.5

	11:grinding	12:Light -assembly	13:heavy -assembly	14:Loading	15:inspec -tion	16:others	17:total
food & textile	0	34.6	26.6	77.6	81.4	131.4	414.2
wood & paper	16.3	14.6	5.5	16.1	16.9	27.2	165.1
chemistry	4.9	9.7	3.9	11.3	11.9	19.2	71.3
rubber & cement	14.8	13.3	3.6	14.6	15.4	24.8	135
iron & steel	4.4	2.6	1.5	4.4	4.6	7.4	47
non-ferrous metals	3.6	3.2	1.2	3.6	3.7	6	38.5
metal products	16.3	14.6	5.5	16.1	16.9	23.3	170.7
general machinery	16.8	15.1	5.7	16.6	17.4	21.3	173.3
electric machinery	23	20.7	7.8	22.7	23.9	33.8	242.6
car & motorcycle	11.3	10.2	3.8	11.2	11.7	15.6	120.7
other transportatio	2.9	2.6	1	2.8	3	4.8	31.2
precision machinery	5.3	4.7	1.8	5.2	5.5	8.8	57.9
others	25.2	22.7	8.5	24.9	26.1	42.2	274.1
total	144.7	169.4	76.4	227.1	238.4	364.6	2052.2

Figure B-2. Japan Potential Substitutable Workers estimated potential substitution rate (%)

	1:casting	2:die cast -ing	3:plastics - forming	4:heat -treatment	5:forging	6:press & -shearing	7:arc weld -ing	8:spot wel -ding	9:painting	10:gilding
food & textile	0	0	98.5	74.4	0	0	0	0	0	0
wood & paper	0	26.9	0	34.3	0	40.3	93.3	36.5	48.2	38.7
chemistry	0	0	51.2	0	0	0	0	0	100	0
rubber & cement	0	0	8.5	44.8	0	100	100	0	27	75.9
iron & steel	5.2	44.3	74.8	3.8	3.7	16.6	38.5	100	26.5	9.1
non-ferrous metals	5.7	17.2	34.8	18.8	31.4	38.6	100	100	61.6	37.1
metal products	51.9	84	100	15.3	76.8	21	33.6	36.1	39.3	25.9
general machinery	26	94.7	100	18.1	43.3	28.4	21	42.9	25.5	68.1
electric machinery	43.3	70.2	23.7	33.5	0	26.3	44.3	39.5	44.4	24.2
car & motorcycle	29.3	29.6	37.5	18.9	36.2	25.4	32.5	23	44	30.1
other transportatio	30	100	61.6	17.4	100.1	27.4	25.3	27.1	26.2	100
precision machinery	53.6	32.6	54.9	20.7	100	35.5	75.3	39.3	51.9	23.4
others	61.5	74.7	33.6	27.2	100	44.8	38.4	58	39.7	30.7
total	27.4	49.5	37.2	27.8	28.9	31.6	39.1	39.8	37.6	31.1

	11:grinding	12:light -assembly	13:heavy -assembly	14:loading	15:inspec -tion	16:others	17:total
food & textile	0	100	76.7	18.7	29.4	20	27.8
wood & paper	52.1	93.9	17.7	14.7	27.1	17.5	29.4
chemistry	100	100	26.6	23.3	30.5	26.3	34.9
rubber & cement	68.2	36.9	100	20.2	15.2	40.3	31.1
iron & steel	12.3	100	19.4	12.2	10.5	20.6	14.7
non-ferrous metals	33.3	60	45.2	23.3	23.1	44.7	32.9
metal products	29.6	40	22.1	23.6	27.4	100	32.8
general machinery	20	33.1	9.1	27.9	23.3	100	27.8
electric machinery	35.5	22	15	33.7	26.1	100	33.4
car & motorcycle	37.3	41.4	21.3	35.9	31.8	100	34.3
other transportatio	35.4	47.8	12	26.3	27.6	50.8	31.2
precision machinery	31.6	16.3	15.6	31.2	26.2	76.9	36.3
others	37.4	38.7	16.4	37	35.4	66.9	39.9
total	33.6	42.5	23.6	22.3	26.2	31	32.6

Figure B-3. Japan the Percentage of Potential Substitutablity

Appendix 3.

Methodological Problems in Estimating Internationally Comparable Labor Matrices

We know of only two studies giving internationally comparable labor matrices (occupation-by-sector matrix). The first was done by the OECD (1969/70) and the second by Zymelman (1980) at the World Bank. Table 3.1. compares the two studies and the proposed IIASA study.

Table 3.1.

	number of considered			basis
	countries	occupations	sectors	year
OEDC (1969/70)*	53	9	ca 12	~1960
Zymelman (198)	26	120	58	~1970-72
IIASA (Propsal)	ca 12	120	58	~1981-84

* Labor matrices with the same classification have been published in the ILO yearbook for several years.

An overview of the IIASA data base is given in Table 3.2. It is divided between the currently available labor matrices, the labor matrices which are promised and "on the way" to IIASA and national matrices which are potentially available and must be added later to coincide with the countries included in the INFORUM system. This table gives the years for which labor matrices are available and shows the comparability of these matrices with the ISIC and ISCO on the 2- or 3-digit level.

In the following we discuss the main problems to estimating internationally comparable labor matrices.

1. The primary data sources for labor matrices are <u>censuses</u> and <u>microcensuses</u> or specific surveys (as in the U.S.). This leads to the following problems:

a) Censuses and microcensuses are infrequent, so that time series data are generally not available.

b) There is often a significant time lag between the completion

Table 3.2. The State-of-the-Art

	Countries	Year	Comparability with		INFORUM
			ISIC	ISCO	
Available	FRG	1950, 1961, 1970, 1982	3-Digit	3-Digit	x
	USA	1970, 1978, 1984	3-Digit	?	x
	Japan	1970, 1975, 1980, 1985	3-Digit	?	x
	NL	1970, 1979, 1981	2-Digit	2-Digit	
	Austria	1961, 1971, 1981	2-Digit	2-Digit	
	Finland	1970, 1980, 1985	3-Digit	3-Digit	
On the way	France	1970, 1982 (?)			x
	Sweden	1970, 1975, 1980 (?)			x
	Norway	1970, 1985 (?)			
	UK	1970, 1985 (?)			
Uncleared	Italy	1970			x
	Canada	1970			x
	Belgium	1970			x

of the census/microcensus and the processing of the data. (For example, the detailed labor matrix for Austria, which was based on the census of 1981, was not available until 1986!)

c) The results of censuses and microcensuses are often not (or only partly) published.

2. The nomenclature of most labor matrices is based on national classification systems. In order to achieve international comparability, conversion to the International System of Industrial Classification (ISIC) and International Standard Classification of Occupations (ISCO) is necessary. The main problems here are the following:

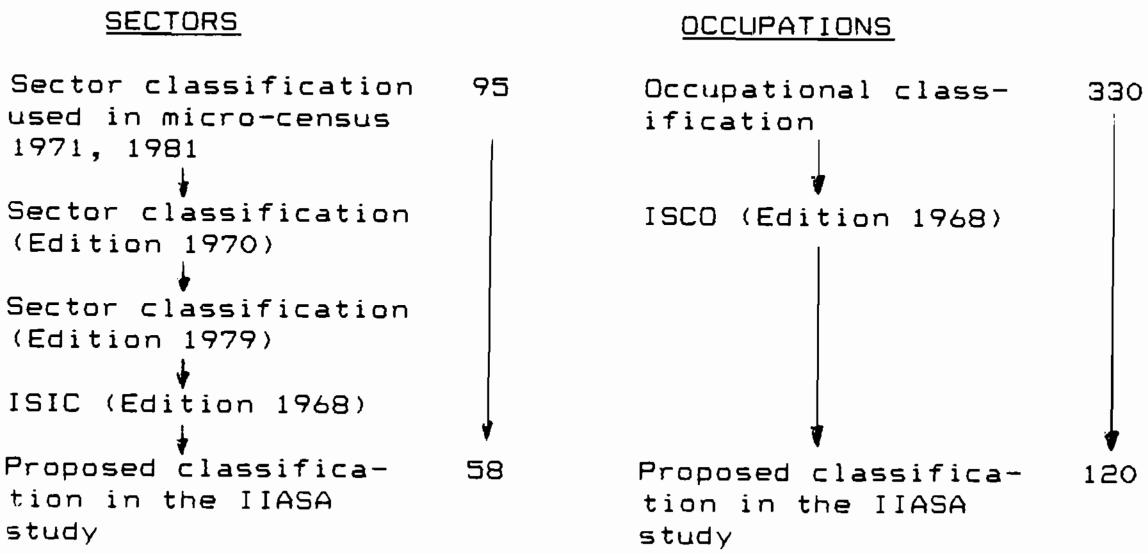
a) In some cases the conversion tables are not available. For example, conversion tables between the US and Japanese occupational classifications to ISCO are not available. The only way to achieve comparability is to make a comparison between the nationally used classification schemes and the ISCO "by hand" (Zymelman, 1986; Norwood, 1986). This requires direct comparison between approximately 1500 occupational descriptions.

b) Comparability between the national classifications with ISIC and ISCO can only be achieved for some countries at the 2-digit level. There are two reasons for this:
   - At the 3-digit level, many national classification systems use a completely different classification scheme, in comparison to the international standard classification (e.g. the occupational classification system for Austria).
   - Labor data on the 3-digit level are collected less frequently than at the 2-digit level in some countries (e.g. the Netherlands).

   This problem is especially important with regard to estimating historical data sets of such labor matrices. The easiest approach is to use Zymelman's labor matrices (c 1970) and elaborate the labor matrices for the beginning of the 1980's using the same classifications. But Zymelman did not simply utilize the sector and occupational classifications respectively from the ISIC and ISCO; rather he reorganized these schemes to be more useful from the viewpoint of his study (educational planning). For instance, he referred to electrical wireman (no. 8-55) as a special occupational group of the major group "construction workers", whereas the electrical and electronic fitters (no. 8-51, 8-52) referred to a special occupational group "fitter-assemblers". This means that the classification of Zymelman's study can only be duplicated when labor matrices with 3-digit subdividions are available.

c) In order to achieve comparability between the nationally used classification systems and the ISIC and ISCO, supplementary computations are sometiomes necessary. Table 3.3 shows the necessary computation steps for the labor matrix of the FRG for 1982.

Table 3.3 Computation Steps for Elaborating the ISIC and ISCO Comparable Labor Matrix of the FRG



As one can see from Table 3.3 one needs 6 different conversion lists in order to achieve comparability.

3. ISCO is in process of being revised by the ILO. It is expected that the revised ISCO version and the manual will be ready for publication by the end of 1988. The proposed changes in ISCO must be allowed for in the elaboration of the comparable labor matrices, as shown in Table 3.4. Some of the features of

Table 3.4. Classification Criteria

		Description and criteria resp.	
ISCO (1988)	ISCO (1968)	Job ↓	... Set of interrelated tasks and duties which belong together in the sense that they are regularly performed by one person
		Occupation ↓	... Set of similar jobs - similar because they perform the same type of work
		Skill	... Skill level and skill specialization required to carry out the tasks and duties of an occupation

the revised ISCO which are important for the proposed IIASA study are the following:

a) The purpose of the revised ISCO is the same as that of ISCO (1968). It aims at classifying <u>jobs</u> into relatively broad occupational groups. A job is a set of interrelated tasks and duties which belong together in the sense that they are regularly performed by one person or that one can expect /educate/train one person to perform them. An occupation is a set of similar jobs, in terms of tasks and duties. "<u>Type of work performed</u>" is the basic selection principle used in the revised ISCO for defining and grouping occupations.

b) The ability to carry out a certain type of work (i.e. to fulfill its requirements) will depend on the possession of the right kind and degree of skill. In the revised ISCO occupational categories will be grouped according to skill level and specialization needed to perform the given tasks and duties (see also Hernstadt/Zymelman, 1980).

c) The "International Standard Classification of Education" (ISCED) will be used to define skill levels in the classification system of the revised ISCO. The ISCED levels reflect the broad stages of progression through the regular educational system. Six categories are created by first defining three levels (first, second, third) and then subdividing the second and third levels into two and three stages respectively. The six-level categories in ISCED are defined in terms of the number of years usually necessary to complete successfully these courses of traning, including the required years of formal schooling.

d) The revised ISCO is concentrated on the macro-levels of the ISCO-(68). It does not change the 1,506 occupational categories of ISCO (1968) per se. Rather, it changes the classification system of the major, minor, and unit groups with regard to the classification criteria (namely, "type of work performed" and the "skill level and skill specialization"). Table 3.5 compares the major groups in the ISCO (1968) and the revised ISCO. Proposals for subdivisions within proposed major groups have been based on broad skill specializations for the first lower level of aggregation, and on more narrowly defined skill specializations for the remaining levels of aggregation.

Table 3.5. Comparison between ISCO (1968) and ISIC (1988)

ISCO 1968		ISCO 1988		ISCED
0/1	Professional, technical and related workers	1	Administrative and managerial occupations	
2	Administrative and managerial workers	2	Professional occupations (fourth skill level)	←-- ≥ first university degree
3	Clerical and related workers	3	Para-professional and technical occupations (third skill levels)	←-- ≤ 14-15 years education
4	Sales workers	4	Sales and services occupations (second skill level)	←-- ≤ 11-12 years education
5	Service workers			
6	Agriculture, animal husbandry and forestry workers, fishermen, hunters	5	Agricultural and food processing occupations (second skill level)	
7/8/9	Production and related workers, transport equipment operators, and laborers	6	Production occupations (second skill level)	
X	Workers not classifiable by occupations	7	Machine operating and assembling occupations (second skill level)	
		8	Elementary occupations (first skill level)	←-- ≤ 5-6 years education

Incorporating these changes in the ISCO in the IIASA study would allow us to refine our analysis of the linkage between the changes in the occupation structures by industries, attributable to CIM, and the implications for educational planning.

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