ECONOMIC IMPACTS OF HIGH TECHNOLOGY

Y. Kaya

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

Former economic research at IIASA focused on comparative studies of structural changes in developed countries. The intensity of these changes has serious, and sometimes severe social implications. One area of current concern throughout the world is the diffusion of new technologies with a high potential in substituting labor in manufacturing and services, as well as drastically changing the existing patterns of international trade.

In the process of formulating an agenda for the research within the Technology-Economy-Society (TES) Program, IIASA organized an expert meeting on "Socio-Economic Impacts of New Technologies", which was held in Warsaw, Poland, from 18 to 20 November 1985. Twenty-six participants from eleven countries and four international organizations discussed possible IIASA research in this field and came to an understanding that IIASA can and must contribute to the development of a conceptual framework for analyzing and forecasting the impact of high technology (e.g. robotics).

Prof. Yoichi Kaya, an outstanding scholar from the Department of Electrical Enginering, Tokyo University, and NMO Secretary of the Japan Committee for IIASA,has been highly cooperative in structuring the TES Program. He stayed with IIASA during July to September 1985 to help us organize the agenda for the Task Force Meeting.

This paper, which was written during his stay at IIASA and presented at the Meeting, stimulated the discussions on the macroeconomic problems of High Technology. We hope that it will also stimulate IIASA staff and other scholars in their thougths about the very complex problem of industrial policy at a time of high technology diffusion on the industrial sector.

Anatoli Smyshlyaev

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Y. Kaya*

Contribution to the IIASA Task Force Meeting on
"Socio-Economic Impacts of New Technologies"
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*Prof. Yoichi Kaya, Department of Electrical Engineering,
The Faculty of Engineering, University of Tokyo, 7-3-1 Hongo,
Bunkyo-ku, Tokyo, and Secretrary of the Japan Committee for
IIASA.

1. RESEARCH ISSUES

Needless to say technological progress has played a key role in the advancement of modern society by supplying better, cheaper, of novel goods. Acceleration of advancement is however no other than acceleration of changes in the society structure which may give rise to serious frictions among members constituting the society.

Introduction of microelectronics into watch industry is a typical example. Use of quartz together with microelectronics in watches dramatically improved its performance/cost ratio, and even a child can buy a watch of high quality at a cheaper price than a small doll. This change is certainly welcome by customers, but induced a number of subsequent changes in the watch-related world. Drastic decline of prices of ordinary watches triggered an essential change in the image of watch which was in the past one of precious belongings, and gave a serious negative impact on these watch companies whose sales were mostly high price watches.

Another impact is on the division of labor in watch industries. Adoption of electronics in place of precise mechanisms of watches inevitably dismissed the workers engaged in manufacturing these mechanisms or transferred these workers to other jobs mainly connected to electronics. For instance, in a Japanese watch company which started production of quartz-based watches in 1976, twenty workers who were engaged in handling of precise machine tools by that time were transferred to other works; 5 for manufacturing of quartz, 6 for assembling IC's and related elements, 6 for production control, and 3 for quality control. [Nation institute of Employment and Vocational Research, Japan (1984)]

Introduction of industrial robots into factories is another example of how strong impacts technologies have on society. industrial robots were introduced first in the early '70s to watch-making industry as a part of automation, and next to automobile industry. [Yoshikawa et.al. (1983)]

Introduction of industrial robots into machine industries saves labor force for welding, manufacturing, and assembling parts and thus improves labor productivity. An extreme case is the unmanned factory fully operated by robots. A well-known example is the factory built by FANUC Company in Japan, which is at night perfectly unmanned and producing robots by robots.

Introduction of industrial robots has apparently the same kind of impacts on society as other automation devices, and the major target of automation has always been improvement of labor productivity. However, one which is different in case of robots is that the speed of its market penetration is drastically fast. According to the report of Japan industrial Robot Association (1984), production of robots in Japan was almost tripled in number and doubled in sales during the period between 1979 and 1983.

Introduction of robots may have contributed much to the economic growth due to the increase in productivity, but we should also take notice that it may give rise to a significant change in domestic as well as international labor markets. Substitution of workers by robots, by definition means a reduction of employment for that work. Growth of the economy due to the increase in productivity may compensate it to a certain degree in the long run, but at least labor transfer is unavoidable.

The international market situation is more complex. Introduction of robots into industries of advanced industrialized countries may strengthen their competitiveness in the international market where developing countries have the comparative advantage due to their low labor costs, and then the former countries may come up again even in the market where they lost their shares [H. Rattner (1983)]. Introduction of robots into industries of developing countries, however, may not be an appropriate counter-measure to this, because

1) labor cost in these countries is so cheaper that introduction of robot in developing countries is not economically so attractive, and

2) reduction in employment even for the short-term will give serious effect on the labor market of manufacturing industries, which is relatively small and fragile in developing countries when compared to these of developed countries.

In sum, rapid penetration into the market of new technologies will certainly bring in benefits to consumers or more generally to the economy, but almost unavoidably be accompanied by frictions in both domestic and international markets. For these technologies to be really beneficial to the society, such strategies are to be implemented that reduce frictions in the markets with as little decrease in positive impacts as possible.

Taking into account that the issues are of interdisciplinary (technology and economy) and international character and IIASA's sales point is exactly on this point, we are convinced that IIASA is one of the most appropriate institutions which can conduct a study on the issues.

For the following discussion to be realistic let me take industrial robots as the target technology and describe possible research items.

1. Identification of penetrability of robots into industries

The study begins with identification of the present state of robotization and prediction of its future. With these knowledge we are able to evaluate the impact size of robotization as a basic information for forming strategies for promoting robotization.

Ayres and Millers(1983) evaluated the potential of robotization in U.S. manufacturing industries from the survey data. This is a good starting point, but from a strategic view point the potential should be known as a function of implementation costs or efforts. In other words what is required is the knowledge about how much robotization will be realized with how much and what kinds of efforts. In automobile assembly lines, for example, welding processes are replacable by playback robots but only with skilled workers who train robots. It means that workers are replacable but only to a certain degree, and that further robotization requires interpretation of welding skills in terms of mathematical language.

The study here required is therefore to review existing manufacturing processes in an orderly way and identify these robotization vs. efforts curves, although it is not an easy task.

2. Identification of impacts of robotization

a. Direct impact on employment

Robotization substitutes robots for human labor, and seriousness of the issue depends on how much labor will be substituted. The degrees differ from company to company, industry to industry, kind to kind in labor force, and country to country. These depend also on costs of robots and functions robots can fulfill, which will change rapidly in time. The employment effect of robotization is to be estimated, with the above factors taken into account.

b. Impact on the domestic economy

The main purpose of robotization is certainly to improve the productivity of manufacturing processes and the quality of products, which help increase competitiveness of produced goods in the market and bring in gains for the companies. From a broader view point, the increase in process productivity may accelerate growth of these industries and then contribute to growth of the national economy. The total economic benefits of robotization can not be estimated without identifying details of this impact chain quantitatively.

c. Total impact on employment

The preceding discussion indicates that robotization gives rise to reduction in employment in manufacturing processes, which will be at least partly covered by expansion of the market in the long run. It is obvious that seriousness of the employment impact will be greatly eased by the latter compensatory effects. Therefore we should estimate how much these effects will be, and if possible in what time span these will emerge.

However, it should be noticed that the compensation is only to a certain degree even if it takes over the first type impact in number. The job pattern in a factory or a company will change and transfer of labor force from the jobs for which robots are introduced to those created by market expansion is unavoidable. Feasibility of such labor transfer is also one of the important research targets.

d. Impact on the international market

Another type of economic impact of robotization is as described before the impact on the international market. Expansion of exports or at least reduction of imports of manufacturing goods due to increase in their competitiveness in the international market gives positive impacts on the national economy, but in many cases with the sacrifice of worsening trade balance of partner countries. It means that the competition in the international market is likely to be a zero sum or almost a zero sum game at least in the short run. All developed countries are certainly members of the game, but NICS (newly industrialized countries) will be more sensitive to changes in market competitiveness of member countries, as structures of their economies are still immature and fragile when compared to those of developed economies.

The study then should first of all focus itself on identification of sensitiveness of both developed and developing countries, if possible country by country, to changes in competitiveness of member countries in the international market of manufactured goods. The sensitiveness also differ from industry to industry, due to differences in shares in the international market.

The second step of the study is to evaluate indirect impacts of robotization. Similar to the impacts on the national economy improvement of the quality to price ratio of manufacturing goods by robotization will give rise to increase in the total demand in the international market. In other words, the competition in the international market can be in the long-run, a non-zero sum game in which robotization gives possible impacts on almost all member countries of the market. The study inevitably will touch upon details of trade strategies which will be discussed later.

3. Investigation of strategies

a. Labor transfer strategies

Both in developed countries introducing robots and developing countries receiving increasing pressures of robotization in the international markets, labor transfer will be one of unavoidable consequences of robotization. Transferability of labor depends on kinds of jobs, age structure and education levels of labor force, mobility of people within the country, and many other factors specific to that country. The cost for training and training facilities is also one of major factors influencing feasibility of the transfer. Time is another factor to be taken into account, since the total effect of robotization on employment will emerge as a function of time as stated before and training people is a time consuming process.

Company and government strategies for labor transfer are to be investigated with serious consideration of the above factors.

b. Strategies for better international division of labor

We know that it is easy to point out where in the international market frictions are, but difficult to propose appropriate measures to ease these frictions. In principle, there are three types of measures:

1) To control trade flows by governmental regulations (protectionism/self-regulation type policy)

2) To find and follow optimum patterns of division of

labor with consideration of changing competitiveness of countries in international market of manufacturing goods (optimization type strategy)

3) To eliminate causes disturbing expansion of demands for new technology oriented goods, and help develop economies of member countries in the market.(expansion strategy)

The strategy 1) has been seriously discussed between Japan and USA, but nonetheless is the "last" best strategy. Both strategies 2) and 3) may be welcome by most countries participating in the trade game, but the basic problem is that we do not know yet exactly what they are. In strategy 2), we should explore the methodology which can provide optimum patterns of division of labor, not only from the theoretical analysis, but from consideration of practicality of such division of labor. (Input-output model approach is one of means but its usefulness to this end is limited.)

Strategy 3) is in principle the first best choice, because the ideal result will be that "everyone gains". However, the disturbing factors are mainly in developing countries where domestic markets are still too immature to generously accept cheaper and better products from developed countries as fruits of robotization and to use them as a good incentive for the market expansion. Labor force is rather inflexible in developing countries because of low education levels of workers. Strategy 3) is in this sense closely connected to the development strategy of these countries. Required on this point as a part of the research is to investigate these strategies in detail and find out those strategies of which expected outcome will be maximized.

The above items are certainly not results of a thorough survey of issues, but may be already too much to be studied within a project IIASA can conduct. There have been a lot of studies in the world which cover some parts of these items, and a survey of such studies is the first but indispensable step of the research.

2. STRUCTURE OF ECONOMIC IMPACTS OF ROBOTIZATION - A PRELIMINARY REVIEW

The socio-economic impact of robots is certainly not a new topic. [For example, H.D.Haustein and H.Maier(1981), B.Friedlichs and A.Schaff(1982), OECD ICCP (1981/2), H.Rattner(1983), R.U.Ayres and S.M.Miller (1983), H.Inose and J.Pierre (1984), R.U.Ayres(1984), and Japan NIEVR(1984)]. However, most past studies investigated the issue only partly or conceptually. Three interesting works among them are by Ayres and Miller, by OECD and by Japan NIEVR. Ayres and Miller made a detailed analysis on the potential of robotization and its impact on productivity, which will be a good basis for the coming IIASA study. OECD reports described employment effect of robotization in OECD countries. These two works however touched only little upon the impacts of robotization on national and international economy. Japan NIEVR (National Institute for Employment and Vocational Research) report deals with the issue in a broader context than the former two, and investigated not only on the direct impact of robotization on employment, but also on the compensatory impact through the causal chains in the national economy. In this sense, the objective of NIEVR study is somewhat close to that of our study, but is still at the preliminary stage so that it may be too early at this moment to investigate on the details of the study outputs. The purpose of this chapter is, taking results of the above studies into account, to illustrate the structure of economic impacts of robotization and review the characteristics of what should be studied in the coming IIASA study.

Impact structure and data availability

Economic impacts of robotization constitute not a single chain but a mutually interactive complex system as shown in Fig.2.1. The left half of the figure shows the impacts at the industry level, while the right half shows how impacts will propagate through the national economy. The element at the bottom of the figure is the impact on export which is connected to the international economic system. Although the details are not illustrated explicitly in the figure, we believe the analysis on this part is as important as those on other parts of the figure.

The first step of the review is to survey availability of data for the analysis on the impact system in Fig.2.1. We know that a lot of data are available on national and international economies, and so the key point is what types of data are available for the variables shown in the left half of Fig.2.1, i.e. those at the industry level.

Industrial robots were introduced only recently, namely, in the latter half of '70s and the only in a few countries such as USA, Japan, West Germany, and Sweden. It means that potential availability of robot data from the statistics is at maximum 8-10 years in a few countries. I tried to survey availability of robot statistics, but up to now I found a detailed sectoral data only

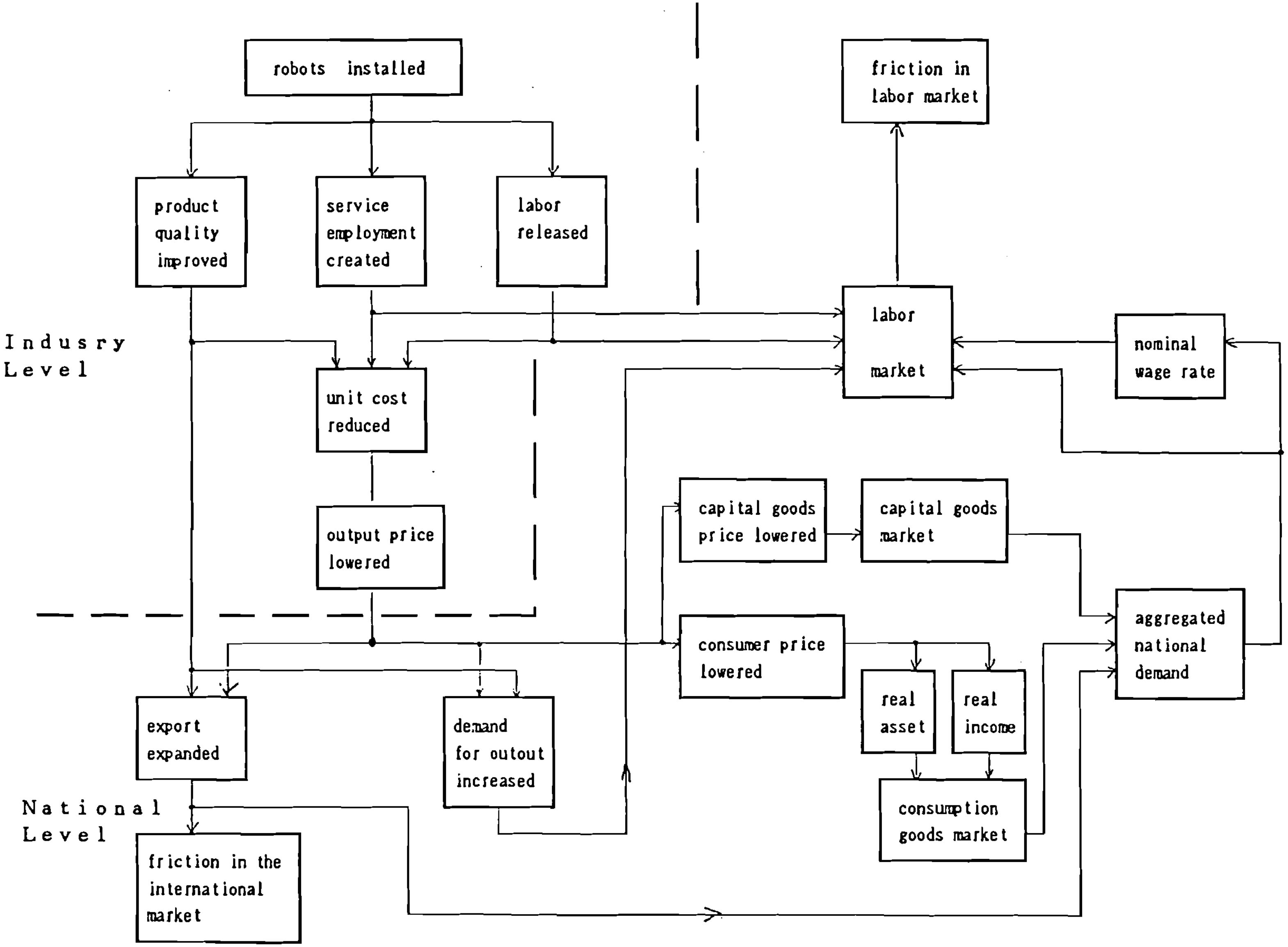

Fig. 2. 1 Economic Impact Structure of Industrial Robots

from my country, Japan. The official machine statistics published by MITI provides data only on total sales and numbers of three types of robots produced per year. However, Japan Industrial Robot Association (JIRA) published another statistics based on their own survey. The coverage of the survey is rather high, around 90% (in terms of number of companies producing robots). The data are compiled as a time series of sectors/kinds of robots matrices both in number of production and in sales. Names of sectors and types of robots are shown in Table 2.1. According to this scheme we have for Japan the most detailed data now available from the statistics published to date. One of the urgent tasks at the preliminary stage of the study is to investigate whether similar types of data are available in other countries.

Labor substitutability

A simple but very important factor to be studied is the labor substitutability, i.e. how many workers are replaced by robots. The total potential was studied in detail in the case of the United States by Ayres and Millers, but another important factor to be studied is the average number of workers replaced by a robot (or unit production of robots in terms of money).

There are a few survey from the engineering analysis, and Table2.2 is according to Lehmann. However, these numbers may differ from industry to industry, from job to job, and in kind of robots. Also robotization may have effects on the labor force not directly connected to the jobs replaced by robots. In this case a more detail survey on real factory data is desirable. It is however not easy to do this kind of task, as it requires collaboration of many factories in details of labor assignment.

An alternative to this is to evaluate labor substitutability through the econometric analysis of real capital and labor data of industries. Japan NIEVR study has done a work along this line, in which they estimated labor input functions by sector and by class of labor. The labor force of a sector in a certain labor class is expressed as a loglinear function of ordinary capital as well as robots being used. However, if we use this type of labor functions, the labor substitution ratio, i.e. number of works replaced by a robot, L_r, varies almost inversely proportionally with the total number of robots, R. At the initial stage of robotization R changes very rapidly, and so L_r. From an engineering view point, L_r may change but within a certain narrow range; from Table 2.2 L_r may lie between 1 and 10. In this sense,

Table 2.1 Production Data of Industrial Robots: Format
(Japan Industrial Robot Association)
(In terms of number)
(In terms of sales)

Sector / Type of robots	A manual manipulators	B fixed sequence robots	C variable sequence robots	D playback robots	E numerically controlled robots	F knowledgeable robots	G-I robot peripherals
1 Food							
2 Textile							
3 Wood, Wood Products							
4 Pulp and Paper							
5 Chemical							
6 Petroleum/ Coal							
7 Rubber							
8 Cement/Clay							
9 Iron/Steel							
10 Non-ferrous metal							
11 metal products							
12-1 boiler/engine							
12-2 construction							
12-3 metal products							
12-4 other general machinery							
13 electric machine							
14-1 automobile							
14-2 bicycle/train							
14-3 ship							
15 precision machinery							
16-1 plastics							
16-2 other non-metal							
17 non-manufacturing sector							
18 export							
Total							

Table 2.2 Labor substitution factor of industrial robots.

		1 shift	2-3 shifts
Industrial	B	1.5	4.0
robots	S	1.4	3.0
Component	B	2.1	6.2
manipulators	S	1.6	3.3
Tool	B	0.9	1.7
manipulators	S	0.43	0.8

B= Battelle Frankfurt

S= Sociological Institute Goettingen

Source: H.D. Haustein and H. Maier
WP-81-152 WP. The Diffusion of Flexible Automation and Robots.

NIEVR approach may not be appropriate for the estimation of L_r.

Another approach is the use of CES production function with robots and labor force as substitutable variables with each other. In this formulation L_r is proportional to the ratio of unit robot cost to wage and I estimated L_r with presently available labor data (sectoral but aggregated for each sector) and the robot data as shown in Table 2.1, taking into account that robot cost includes not only the price of a robot but many other factors connected to installation and operation of a robot. According to the estimation results, L_r lies in most industries between .3 and 6, which shows a good coincidence with Table 2.2. With this as a basis, I believe that actual values of L_r may be estimated by an elaborate analysis on the robot and labor data. However, I stress that a survey of factory data, even if the number of samples is small, is always useful for reinforcing the results of statistical estimation.

<u>Creation of service employment</u>

Robotization will release workers engaged in manipulating machine tools, welders, and assembling elements, but instead give rise to increase in jobs connected to software production and maintenance of robotized systems. A survey on this aspect is indispensable for evaluating the total impact of robotization on employment and planning labor transfer strategies.

<u>Impact of robotization on output price</u>

Introduction of robots into manufacturing industries helps reduce unit cost of production, henceforth output price, and then give rise to increase in demand both domestically and internationally. It also helps improve quality of products, which contributes to increase in demand. Furthermore, reduction in unit cost of production helps increase the capital investment, and expand the demand for capital goods.

All these linkages should be carefully studied in the framework as shown in Fig.2.1. A preliminary analysis has been conducted for the purpose of evaluating the order of impacts along these flows. The first is to evaluate the impact of robotization on output price. For this purpose, impact of improving labor productivity on output price is estimated in the following way.

1. The simplest and probably the most direct expression of robotization in terms of economic variables may be improvement of

labor productivity, or Y/L where Y is the output and L is the total number of workers. The past data shows labor cost/output ratio, C_l/Y, is almost inversely proportional to labor productivity. (See Fig.2.2. The similar trends are seen also in many other countries)

Let $C_l/Y = f(Y/L, P_c)$ (2.1)

where P_c is the consumer price index.

2. Now the output price p is assumed to follow equation (2.2)

$$p = g(P_m, C_l/Y) \qquad (2.2)$$

where g is a linear function, P_m is the price of material input and C_l/Y is the labor cost/output ratio. (By a simple analysis on CES production function it is easily seen that p is a function of C_l/Y, if the total number of robots are relatively small when compared to the total number of workers).

3. In the statistical analysis on Japanese data for the period of 1973-81, both equations (2.1) and (2.2) have high goodness of fit in most industrial sectors. Then the impact of change in labor productivity on the output price is calculated by these two equations. The results indicate that the relative sensitivity of output price to labor productivity (i.e. d logp/d logl where l is Y/L) lies between .4 and 1.2 for most industrial sectors. In other words the impact of robots on output price is roughly the same size as the impact on labor productivity.

Connection to a national economy model

The second important part of the system in Fig. 2.1 is the right half of the figure where impacts of lowering output price and improving quality of products by installing robots propagate within the national economy. Econometric models may be the appropriate tools for the evaluation of these impact flows. We have a few models developed for the analysis of Japanese economy at hand, which may be extensively used for the analysis. This possibility should be carefully investigated in the coming study.

Again a simple analysis has been made on the sectoral demands of manufacturing industries, to evaluate the order of impacts. The demand for each industry is expressed as a function of the income level and the price of the sectoral output price. Goodness of fit of the demand equations are high in most industrial sectors, and the elasticity of sectoral output with regard to output price lies between .3 and .7 in most industry in

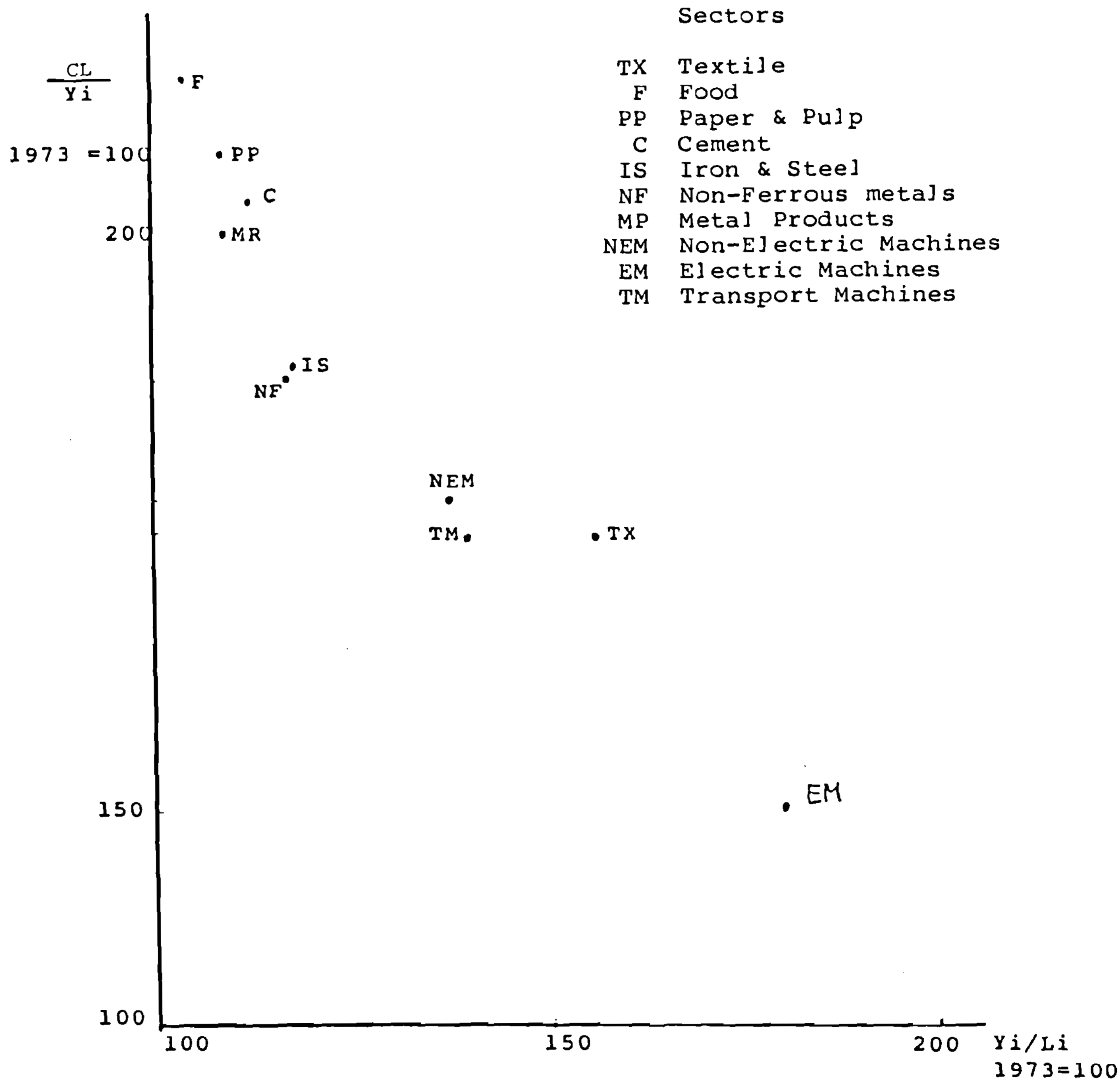

Fig. 2.2 $\frac{CL}{Yi}$ vs. $\frac{Yi}{Li}$: 1981 Japan

which the elasticity is only about .15. It indicates that changes in output prices of manufacturing industries due to robotization will give rise to a remarkable change in the growth pattern of the national economy.

International impacts

The impact of robotization on the international market situation is one of the major targets in the coming IIASA study, as the impact is connected mainly to the interaction of developed countries and NICS in the trade market. A multi-national economic model may also be a useful tool for the analysis on this aspect, and we foresee with a high probability to have collaboration of existing international models and modelers.

However, we should also notice that the essence of real frictions can not be seen only by an econometric model. To evaluate effectiveness of possible strategies to minimize frictions, we should investigate on details of trade and labor market situations, together with the analysis via econometric models.

3. CONCLUDING REMARKS

This paper aims to present issues connected to economic impacts of high technology, especially robotics and to give some concrete ideas about elements of the impact system through a preliminary analysis. However, it is not what I intend to confine the discussion in the meeting only within the framework envisaged in this paper. Rather I intend to stimulate the discussion in a broader context by providing a material as its starting point.

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