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The Macroeconomic Effects of Microelectronics

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7 The macroeconomic effects of microelectronics

Gunnar Eliasson, President, Industrial Institute
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I believe it was Ludwig Wittgenstein who said that truth depends a lot on how you look at it. This is especially true in the context of microelectronics.

We talk about microelectronics as a revolutionary technology and at the hardware level it is certainly impressive, to say the least. Here we shall examine the effects of this revolution at the aggregate economic level. The important question is just how revolutionary is it at that level? On the one hand, there is the growth potential of this new technology, which has been emphasized by my Japanese colleagues. On the other hand, frightening prospects of mass unemployment have been raised by many and various publications from Europe.

I shall try and elaborate on the studies made into these matters at the Industrial Institute for Economic and Social Research, in Stockholm where I am based. I have a sizeable box of literature at home on the subject. On unemployment prospects, the pessimistic type of literature falls into two categories. In one, the authors tend to emphasize the effects of electronics on the processes of industry alone. They see only that the processes are affected, not the products as well. Furthermore they tend to pick one or two extreme cases and then generalize to the whole of industry. From this they conclude that there will be mass unemployment tomorrow.

The other kind of literature adopts a more theoretical approach. Various model structures are devised, some of which are purely theoretical, some empirical, but all have a certain structure that illustrates what Wittgenstein said. In fact several of these models lead to unemployment however you operate them. I can quote a number of cases where the models lead inevitably, when you examine their structures, to unemployment. My aim is to define the problem in macro terms and try to show the effects on economic structure—particularly on output, costs and unemployment.

The literature tends to agree that, historically speaking, technological improvements are necessary for growth. The graph in Figure 1

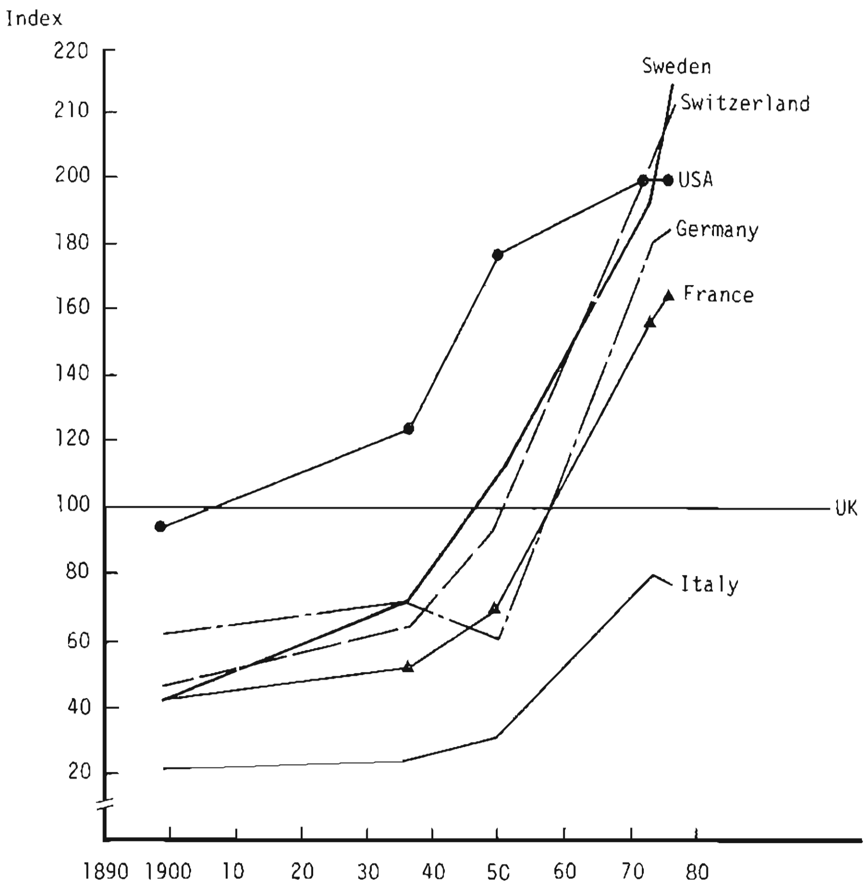

Figure 1 GNP per capita in different countries 1890-1975. (Index: UK = 100.)

shows economic growth, that is the change in GNP over the last eighty-odd years, with the datum of 100 being the GNP of the United Kingdom. You see a tremendous difference in growth rates measured over this considerable period. Sweden and Switzerland have performed quite well, although recently the Swedish authorities have had cause for concern.

The question is: to what extent will microelectronics affect the future projection of growth? Is it a really revolutionary technology when looked at at this level? I doubt it. Anxieties about unemployment are very exaggerated. We cannot find any real substance in the claim that electronics or any other technological change will create unemployment on any scale. But it will create structural change.

As far as production is concerned, our basic conclusion is that electronics enters the production processes, in manufacturing in particular, in a very gradual fashion. It has done so in the past and the case studies and interviews we have done do not suggest any acceleration of the process. And there are other factors that are holding development back and slowing down expansion. So it may be that microelectronics will not generate growth any faster than that experienced in the early 1960s which arose from very different causes. One example of these causes relates to economies of scale, which gave tremendous increases in productivity in the steel sector, which led to considerable structural change in that industry and elsewhere. If you look at this and compare it with what we have learned from our studies of electronics and its applications, it is by no means indisputable that expansion will be faster and more vigorous than in the past.

A point I would like to emphasize is that economists analysing the economy, or even sectors within it, tend to regard the economy as one huge machine in the aggregate. This is quite wrong. If you look at the economy as one big machine, you miss many of the aspects of technical change and its effect on growth. Nevertheless technical change in its various aspects seems to explain a great deal of growth.

We should keep in mind the expression 'structural adjustment', which is a micro-to-macro effect. This is illustrated by the three-way diagram in Figure 2. Thus there are three elements in our study: case studies, a model of the Swedish economy and studies of technical effects at plant level.

The model of the entire Swedish economy is necessary because the study of the effects of electronics on technical change is typical of what economists call a general equilibrium problem, in which all parts of the economy are affected by one change, and the whole model has to settle down to a new equilibrium point before the final effects of the original change can be sorted out.

The complexity of the problem can easily result in misleading conclusions and I believe that this has happened in a number of studies. So we have a micro-macro model that includes a number of real firms in which one can identify technical change in the form of new investments. The model is fed into a computer, and a factor called 'technical change' can be varied to see the effect on the economy as a whole. This factor has been estimated for the twenty-year post-war period. The important thing is that we have measured technical change at plant level.

The next step in our study for the Committee on Electronics and Computers in Industry is to try and reach some sort of conclusion

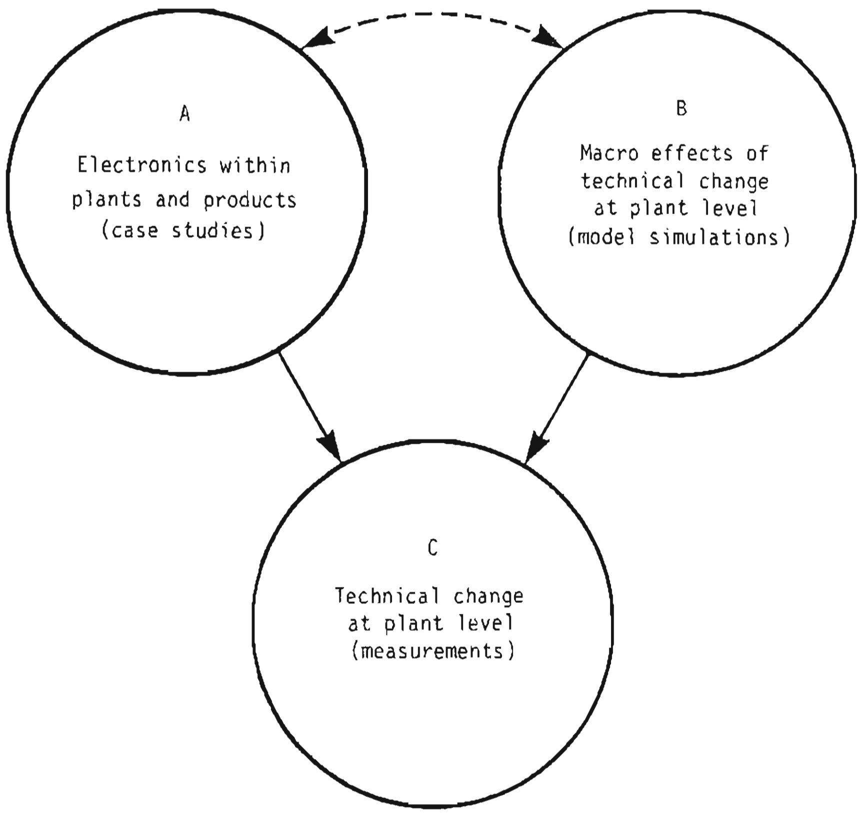

Figure 2 Electronics, technical change and the macroeconomy—the empirical method.

on the effects of technical change on the economy. Referring to Figure 2, once one has established some sort of relationship between A and B, one is able to draw some indirect conclusions about the interaction between A and C, about how electronics may affect the macro side of the economy, especially unemployment, growth, and structural adjustment. One cannot, I believe, approach this problem in a partial study, calculating the effect on labour of one single element in the production process, as one can miss so much. The danger is the tendency to make a big thing out of something that is quite normal and has been going on for years.

Another difficulty is scaling: just because one per cent of electronics is introduced into an application, this does not necessarily mean that a one per cent change occurs in the technical change factor. Technical change in one industry often has a strong effect on unemployment in sectors of other industries. This has happened in

Swedish industry and elsewhere. Structural change in the textile industry over the last thirty years has led to a reduction in the demand for wool, causing sheep farming to decline to one third of its former size, which implies the closure of one medium-sized sheep farm every month for thirty years. That is a sizeable change, a structural change that has been going on ever since the war, and a much larger change than the one we are seeing as a result of the introduction of microelectronics.

The key word behind technical change is structural change, and the fact that the necessary adjustments simply come along as economic forces dictate. This has been going on, especially in the faster growing economies, in the post-war period, but what is happening now in the Swedish economy is that a deliberate policy has been adopted to slow down this change. We have tried to break down the 'residual factor of technical change', that is, to analyse the part of the growth of industrial output not explained by the effect of investment, capital growth, and labour change. This we have done by moving to a macroeconomic model from microeconomic models and from separate studies.

The traditional production function leaves about 75 per cent of growth in industrial output to be explained by this domestic technical factor, in Sweden. In the USA the same measurement produces a figure of about 30 per cent. When we examine the 75 per cent residual at sector level, we find that about 30 per cent of the residual can be explained by structural change, keeping productivity change constant in each sector. We can then break the sector down into company or plant level, and at this level a further 30 per cent of growth is found to be due to structural change between companies in that sector.

At the company level we find that of the residual of 75 per cent of growth in output, half of it is explained by structural change between firms, holding productivity constant within each firm.

Now, going from micro to macro, we have found that perhaps more than 50 per cent of changes in production goals can be generated in our model by varying structural changes in a sector. We have also found that differences between countries in industrial output over these long periods (shown in Figure 1) can also be generated on our macro model simply by varying the rate of structural change, after the same technical assumptions of new investment in industry. This defines how the market operates in the market place.

So, even if identical levels of investment of the same technical quality are going into industry each year, one can generate very different growth rates in the economy by varying the parameters that specify how the economy operates both in the market place and as affected by social policy.

What I want to emphasize is that technical change affects growth significantly in the very long term, but there are other factors on the social side that affect growth as much, and even more: how the economy is organized; the scope for incentive; how policies are operated by governments; if one ignores these factors one is disregarding a very large part of the growth process and of what should be meant by technical change.

Table 1 shows the results of a large questionnaire study in which we talked to a large number of businessmen and technical people in a large number of fields about labour productivity development in various production processes over a long period, and one can see the various rates of change that were estimated by these people. On the whole, we estimated that on average, labour productivity in the most efficient plants with new investment has been increasing only by some 2.5 per cent a year, over the twenty years between 1955 and 1975, even with the competition faced by Swedish industry. This should be compared with an aggregate rate of productivity change of about 6 to 7 per cent over the same period; a substantial difference that structural adjustment probably does much to explain.

Now let us return to the role of electronics in this process. It should be emphasized that to link microeconomics to macroeconomics one has to go by way of something that can be measured, and that it is possible to measure what is called 'technical change' at the company level.

In general, it seems from the case studies carried out both at my Institute and by the Computer and Electronics Committee that electronics is becoming very important in guiding the flow of production in a factory. We have found several cases where enormous productivity gains have been made simply by reorganizing production flow, without any new machinery or new gadget being installed. This shows that to obtain this sort of gain it is not necessarily the hardware that counts, but the organization of material flow round a plant. In several cases we have found electronics stores control systems keeping control of inventories so that goods can be found when needed, and unnecessary inventory kept to a minimum.

On the hardware side, the direct use of electronics in the production process in robots, automated production, and so on has been held back by a number of things. Mechanical technology is lagging behind sensor equipment, for example. But above all there is a knowledge of the various aspects of the production process which has for a long time been distributed around a plant or factory among

Table 1 Examples of labour productivity change in new plants 1955-1975

Industry	*Productivity measure*	*Annual percentage change*		
		1955-1965 (1)	*1965-1975 (2)*	*1955-1975 (3)*
Extractive industries				
Iron ore industry	Tons of rock/man hour	7.9	3.4	5.6
Forestry (logging)	m^3/working day	7.2	11.6	9.4
Raw material processing				(5.9)
Pulp and paper industry	Tons/man hour	11.6	0-3.4	5.6-7.4
Ethylene production	Tons of ethylene /man hour	14.5	6.0	10.2
Intermediate goods				(3.0)
Commercial steel	Tons of crude steel/man hour	6.0	4.8	5.4
Steel pipes	Tons/man hour	3.6	5.8	4.7
Steel forging	Tons/man hour	6.5	2.5	4.5
Investment goods				(2.6)
Heat exchangers	m^2 of heat absorbing surface/man hour	7.2	7.2	7.2
Hydro-power generators	MVA/man hour	1.0	3.6	2.2
Marine turbines	kW/man hour	7.2	-4.5	1.2
Shipbuilding	Tons of steel/man hour	7.2	1.0	4.1
Consumer goods				(0.4)
Pharmaceuticals	Tons/man hour	1.4	2.5	1.9
Food industry				
Canning and freezing	Tons of finished goods/man hour	13.1[a]	4.3	5.4
Sugar industry	Tons of beets/man hour	2.7[b]	4.1	3.4

[a] Refers to 1960-1965.
[b] Refers to 1960-1970.
Source: B. Carlsson and G. Olavi, 'Technical Change and Longevity of Capital in a Swedish Simulation Model', in G. Eliasson (ed.), *A Micro-to-Macro Model of the Swedish Economy*, IUI Conference Report 1978: 1, IUI, Stockholm 1978.

often highly skilled personnel, and it is very difficult to develop this and bring all the skills together so that a centralized computer can duplicate the process. This demonstrates that what is often called the software side, and what economists call 'human capital', often poses an important restriction on the application of electronics, reducing it to slower rates than one would expect on reading some of the publications on the subject.

As an analogy, Gutenberg invented the printing process several hundred years ago, and that was as revolutionary a technology as electronics is now. But printing was not generally applied and used on a large scale until enough people could read and write, and that took a long time. That is the 'human capital' aspect.

One thing we have learned is that the introduction of electronics techniques at factory or plant level is very piecemeal. One cannot, so to speak, automate the whole production chain immediately, one does it step by step. At each step of the automating process there may be a tremendous effect on the productivity of that production step, but at the overall factory level the effects of automation are only gradual, and not faster than productivity gains from earlier changes in technology. We have found a number of cases where larger effects on total factory productivity have been obtained by conventional means than have been gained from electronics.

Technical change, as measured by traditional macroeconomic methods, has resulted in the conclusion that it has been labour saving in character, rather than capital saving—at least in the post-war period until recently. But we have found that the introduction of electronics into Swedish industry has resulted in changes which are more capital saving than labour saving. Admittedly this is a conclusion that I have not entirely accepted as yet, because some of the measurement techniques are not exactly what one would like to see used, but we have seen it happen and people have pointed it out to us. The saving in capital is not usually in machinery but in better monitoring, keeping down inventories, outstanding debts, etc. These can mean sizeable improvements in profitability for companies if used intelligently.

One important question is whether this new technology will mean a general increase in the rate of technical change as compared to the past. We have found no evidence to suggest that this is necessarily the case. We may be wrong, but it is not obvious at all that it is true, which of course leads to the conclusion that we may be able to use the past to assess logically the future macro effects of the new technology.

One new aspect is the realization that electronics is a universal technology with many applications in all countries. We have found in our simulation experiments that if a country is lagging behind in technology, it is affected in terms of unemployment by the faster development of the same technology in other countries. The effects of the new technology in other countries are transmitted to the stragglers by international trade, price cuts, etc. And if the effects of new technology come to a country in that way, the effects on unemployment and growth are much harder than if the technology had been adopted by domestic industry. Thus if one is going to be concerned about the effects of these technologies on employment, one should worry about other countries taking the lead in introducing these economies, rather than one's own country.

We found in our simulation experiments that in the long run the main practical effects are more or less growth in income in the economy. In the short term one may find the expected effects on employment, namely that the acceleration of technical change through electronics produces more employment and not less, and vice versa. But the long term macroeconomic effects are very small and disappear quickly. On the other hand, the structure of employment is changing. People move between firms and change jobs within firms. Technological change tends to force this change in structure, as all other technological change has done, but that is nothing new: it has been happening all the time in Sweden for the last hundred years, and in most other countries.

8 Discussion

KEITH PAVITT
Senior Fellow, Science Policy Research Unit,
University of Sussex, UK

The electronics sector is the most fundamentally important industry of the seventies and eighties. That is obvious from several of the papers presented by people from the industry, both from Europe and Japan. It is the breathtaking pace of the changes in costs, reliability, and innovation which set microelectronics apart from other industries.

I must, in passing, disagree with Professor Reese, who argued that the pace of technical change is determined by the social relations of society, the 'power structure' as he would have it. I believe the pace of technological change in semiconductors and microelectronics is determined by what science and technology can offer. If the power structure could have determined the pace of technical change over the last decade, people would surely have ensured that we had an equivalent rate of change in energy. They would have ensured that we did not become so reliant on expensive Middle East oil and on OPEC as we have done.

The 'power structure', and that includes industry and government, is not yet able to stimulate such a rapid rate of technological change in the energy industry. This is because our understanding of the basic technology and the possibilities for change are different in the energy and electronics industries.

This having been said, I think the rapidly developing electronics industry clearly shows enormous possibilities for applications. We heard earlier about the two 'C's—computers and communications; in another context, we also heard about the three 'E's—electronics, exotic materials and energy. I am convinced that advances in the electronics sector could be harnessed to solve some of the wider economic and political issues and problems faced by Western societies. Many of these have been identified by the contributors—ways in which electronics could be applied to save energy; increasing the scope of and reducing the cost of communications; improving manufacturing processes. These would not necessarily destroy employment. On the contrary, they ought to create enormous investment and hence job opportunities.

My favourite anecdote for the future relates to the church clock being transformed into a wristwatch. Thus, what had been a public service, the church clock, has been taken over by and transferred to a private commodity—the wristwatch. One can see many possibilities in the future for various public services, particularly in information processing and education, being superseded by consumer durables through the convergence of telecommunications, the computer and television. This will happen both in the home and the office.

This pointer for the future leads me on to the second point I wish to make. But before doing so, I feel it needs to be stressed that we are still living in the dark. We are in the middle of a revolution, and at this stage it is extremely difficult to know exactly what is happening. The point I would make is that nobody—be they academics, industrialists, economists or technologists—can say at this stage with any degree of confidence just what the effect of this revolution will be on jobs, on the efficiency of manufacturing industry, or even on the size of industries.

I would remind you of two previous attempts at forecasting the possible implications of radical technical change. The first was during World War I with the introduction of radio. This was first of all seen not as a means of mass communication, but rather as a method of local communication, initially between ships, then between armies or groups within armies in the field, and eventually between private companies. It was only in the 1920s that the possibilities of radio as a means of mass communication were recognized. I think the pluralistic nature of the social system had a great deal to do with the spread of the use of radio; pluralism is even more important today.

The second example relates to the kind of predictions that were being bandied about in the early and mid-fifties about the development of markets for computers. Market forecasts for the uptake of computers looking just five years forward were wrong by a factor of ten. The predictions were ten times too low.

My proposition is that today we are equally in the dark when it comes to forecasting the effects of technical change. To put forward an intelligent policy for action, we must collect information on a much more systematic basis. We need better case studies from industry, from commerce, and better prepared macro-studies on what is actually happening, not on what is being predicted. Studies of the kind presented by Fujitsu, showing the rate of penetration of microelectronics in various products; studies of the sort being prepared in Sweden by Dr Eliasson's group. Only through such authoritative studies can we understand just what kind of revolution we are in, and in what direction it is heading.

The third point relates to my being somewhat confused about one of the recurring themes of the presentations; the relative strengths and weaknesses of Japanese technology. I have heard it said by both Europeans and Japanese that Japanese technology has not been particularly original. We know the story that in the 1950s and 1960s Japan was a very effective imitator of foreign technology. Japanese companies bought lots of licences for technologies already operating in other countries, and improved them. Some of the papers presented here, by both European and Japanese delegates, suggest that this is still the case—that the Japanese are still not strong in basic technological research. Their *forté*, we are told, is still picking up innovations from other countries, improving them, developing them for their own purposes, scaling them up or down as required, and even completely re-engineering them to meet the needs of mass production. Sociologists suggest that the reason for this is that radical inventions require radical individuals, and the 'consensus decision-making process' prevalent in Japan means that the development of such radical individuals is not encouraged. If this 'weakness' in the Japanese system continues, innovation will never be a strong point in Japan.

At the same time, Europe wants, even needs, to learn things from Japan. What are these things? I would also like to enquire whether the Japanese are interested in allowing others to know in depth about their particular technological strengths? I am dubious about this apparent lack of innovative capacity in the Japanese system. It seems to me that many of the advances that one recognizes as important in the electronics industry are 'systems innovations'. Systems in products, systems in relating products to processes, electronic systems for improving the home, the office and, just as important, the factory. And it appears that the consensus approach is not so bad when it comes to developing systems. One only has to look at the string of successes from Japan to appreciate this. I would certainly like to clear up some of these apparent contradictions and ambiguities and hope that in the following pages we may glean exactly where Japanese technology may be heading in the future.

My fourth point relates to policy, and it will probably be considered an outrageous argument coming from someone who used to work for the OECD, an organization dedicated to free trade. But

I feel that given the importance of electronics technology, it is completely unrealistic to expect that the economic laws of comparative advantage, as set out in textbooks and outlined in discourses at international conferences, are going to be allowed free play. They were allowed to work in the past in all the other major industries, such as steel, machine tools, and motor cars. One country normally had an advantage. But the point is that in the early stages of all these sectors there were clear leaders.

More recently we have seen, for example in computer technology, that other countries have not allowed the early and almost monopolistic lead held by the USA to continue. By various means—giving their companies subsidies or erecting protectionist barriers—other countries began to build up their own computer industry. The interesting pointer for the future in this context is just how Japan will react. Will it develop a more international stance as regards its computer sector?

In the past there is no doubt that Japan practised, extremely successfully, 'infant industry' policies. By that I mean it protected its own markets for new technology products while they were in their infancy and while they learned about the foreign competition and built up their own manufacturing and marketing strengths. Japan was a follower in most of the major waves of investment and innovations that I have mentioned earlier. The leaders tended to be in Europe and the USA. I wonder if this will be the case with electronics? Will the Japanese be followers or leaders in the development of this important new technology and investment opportunity? If they become leaders, I fear they might have a few painful lessons to learn. How will Japanese companies react to Americans or Europeans stealing or imitating their technologies or inventions? How will the others learn to imitate Japanese technology? Will they be successful? To what extent will they be able to absorb foreign technologies and possibly work practices?

Here are surely some interesting contradictions and challenging problems. The Europeans may also have to learn, and possibly copy, Japan's method of coordinating industrial policies. We hear a great deal about the Japanese support programme for very large scale integration (VLSI) technology. Should (or could) Europe follow a similar path? Would such a policy be appropriate for Europe?

These are just some topics to stimulate our discussion.

MICHIYUKI UENOHARA
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In reply to Keith Pavitt's third point concerning the relative strengths and weaknesses of Japanese technology, let me reverse the question and relate how we in Japan perceive European attitudes and technologies.

We think Europeans are very strong in innovating 'seed' technologies, but somewhat weak in developing these for the benefit of mankind. Japan, on the other hand, is extremely adept at the practical exploitation of known and developed technologies, and even better at exploiting 'seed' technologies. We are aware of these differences, and consider on many occasions and in many committees and working groups how we can diversify and change these attitudes.

Many Japanese see the 'conservativeness' of the national character as a major cause of this lack of innovative ability. Others disagree with such a simplistic analysis. I feel that the environment in which we Japanese have lived in the past has had a big influence on our technological development. Overall, Japan has been a peaceful country, and environmental conditions are not harsh. We have at times been isolated from other continents and have had few wars with neighbouring countries. The relatively small population we had before the Meiji age ensured sufficient food for all the population. This fostered a conservative attitude in the people, and any changes have been evolutionary rather than revolutionary.

More recently, we realized that we needed more technology to change with the times. Naturally, we started looking to other countries, Western countries, for solutions. We adapted these in many instances, made them better and more suited to our needs and culture. We wanted to bring these changes about quickly, so we needed to learn as much as possible from others. In the process, Japanese society and the environment changed greatly. We have experienced a population explosion and now cannot support ourselves from our own resources. We have become very dependent on others for energy, be it coal, oil, or nuclear. In future, anything could happen: things are very unstable. We have many social problems and we have to tackle these in our own way. We cannot wait for others to solve the problem and show us how it has been done.

One aspect of this position is an urge to overcome these problems through the development of new technologies such as electronics, which could also help other nations. That is what we are talking about. We think we can and we certainly want to contribute in some way. We do not pretend to have all the answers. We know we have to rely on Europe and the USA to come up with new technologies that we can refine, adapt and improve. At the same time, we should be able to contribute our quota of technologies and techniques that could be adapted by other nations if they wished to do so.

The crux of my argument is that, because the Japanese social environment has changed so dramatically during recent years, I think we will in the future be challenging others in being first with new technological innovations.

GUNNAR ELIASSON
President, Industrial Institute for Economic and Social Research, Sweden

I would like to challenge several aspects of Keith Pavitt's provocative propositions. One of his arguments states that electronics might in some way change the technological leadership patterns between Japan, Europe and the USA, and on a fairly large scale. He maintains that to some extent this has already happened. I feel, however, that the very nature of this new technology is, as we have all agreed, universal. It is very difficult to be a technological leader in every field. I have difficulties in accepting that one geographical area in the industrial world could become a leader across a whole sector like electronics. There has to be a changing distribution, and this is really very normal, and particularly so in a sector such as this where things move so fast and new applications crop up all the time.

The other argument is that being a technological leader is not necessarily the same as being a leader in international trade. Yet Japan is already being talked about as unassailable in electronics. The suggestion that Europe and the USA should accept this and seek leadership in other fields not related to electronics is one I cannot accept.

Returning to the use of the term 'revolution', I do not know what it means in this context. Just how long can it go on? One thinks of a revolution in terms of a sudden change that occurs over a certain time. The emergence of a new technology to maturity can last a very long time. Much patience is required before it starts to affect production and produce economic benefits leading to sustainable profits and changing trade patterns.

I feel that this 'electronics revolution' we keep talking about will go on for a long time. And when we look back on what has happened, even though it will be possible to pinpoint a number of instances which were revolutionary, the overall effect will not be seen to have been so great, compared to all the other things that happened during the same time, or even in the past. So I would like to ask whether this electronics revolution really is so unique? In economic terms, just what are its special features? Can we use the experiences of the past to assess the implications of the changes that are being forced on us? Finally, to echo Keith Pavitt—are we really so much in the dark about electronics?

DENZIL DUNNETT
London Representative,
Scottish Development Agency

I wish to make a few comments from perhaps an unusual standpoint, namely that of an agency wishing to attract electronics companies to a part of Britain.

In considering cooperation between the Japanese and European electronics industries, I think that here, as in other sectors, there is, and always will be, a certain amount of cooperation, and there is also bound to be continued competition. That is true for companies within the same country and between countries. An example of this was the description of Japanese research into very large scale integration (VSLI). At certain levels, the leading Japanese companies were able to pool resources and collaborate; at other levels, they maintained their competition.

One has to recognize that while one looks forward to collaborating with our Japanese colleagues, there is going to be some fierce competition between us. That is after all the life blood of international trade—the way we run our economic system.

Returning to Keith Pavitt's third point, he noted that there were certain weaknesses and strengths on both the Japanese and the European sides and raised the question: 'What do Europeans wish to get from Japan?' Here, I would like to offer some comments on the reasons why we in Scotland welcome more Japanese investment, particularly in electronics; and I would like to comment on what we might have to offer them. I think this will also be relevant to the point that Gunnar Eliasson raised, since some of the advantages that we hope to derive from having a greater Japanese presence in Scotland are of a general character while others are, I think, specific to electronics.

Scotland certainly looks forward to benefiting from being subjected to some of the Japanese companies' management techniques. We admire the way in which Japanese industry has managed to overcome some of the contradictions that have impeded the progress in productivity in our industries. That of course applies to all industries, not just electronics.

There is another point which also applies to many industries concerning the proportion of resources a firm commits to research and development. I think that in general, Japanese companies spend more on their R&D budgets than is the norm in Britain. One of the lessons that we in Britain are slowly learning is that we will have to increase the proportion of our resources devoted to research and development to a level much nearer that found in Japan. Again, this is a general point, but one which is particularly relevant in electronics, where obviously R&D is vital.

There is another reason why we are keen to develop the electronics sector in Scotland, and why we are actively seeking a greater Japanese presence, and that is the key position of electronics in the total industrial scene. Here, I must concur with Keith Pavitt. There really is something essentially unique about the role of electronics, in the way that it could transform and help all other industries. For example, traditional industries in Scotland, such as textiles, have suffered a major decline, but we now realize that the application of electronics to such an industry could offer it renewed vitality. This could be true for many other of our industries that are at present declining. Although as has been stated we have to be prepared to see our older industries simply vanish, while we adapt to more modern technologies, I feel electronics could play a key role in modernizing industry as a whole. That is one reason why we are developing and encouraging electronics firms to thrive in Scotland. We are, I emphasize, particularly glad to see Japanese companies opting to come there. We know that thanks to their commitment to R&D, and to their management skills, the Japanese have gone a long way towards the ideal way of manufacturing electronics products, and the goods they produce will enable other local industries to establish a lead in the future.

It is not, I think, for me to say here what we have to offer them in return. But we know one of the main reasons why Japanese companies are looking to Scotland is because they want to establish a foothold in Europe. There is no hiding the fact that they are taking the European market very seriously, and they see a manufacturing presence in Europe as essential for the increase of their market penetration. There are naturally other reasons why our Japanese colleagues are coming, but to my mind that is the fundamental one, and it seems to me to be a reasonable balance. We in Scotland are looking forward to getting from the Japanese rather different things to those they are seeking from us, but it seems to be a very reasonable exchange and a reasonable basis for increased cooperation.

CYRIL SILVER
Directorate-General for Research,
Science and Education, Commission
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I feel that this discussion, as with many other recent commentaries on the subject, places far too much emphasis on the revolutionary versus evolutionary aspects of what is happening in electronics. If I am correct, we are wrong, for many reasons, in picturing this as a revolution at all.

The first of these is that revolutions are feared and generally resisted, whereas evolutionary processes are much more readily accepted. But if you look at the time scale, although science and technology have been developing very rapidly during the last fifty years, the applications that we are now talking about in industry, in our homes and in our offices have really been very slow to arrive. As has already been pointed out, even though the market for computers might have been under-estimated when the first market predictions were made, computers are only now beginning to permeate our lives to the degree to which many prophesied they would in the 1950s.

Similarly, if one looks at the changes taking place in our offices today, it is certain that very few use word processors to the extent that they could. There is a reluctance to change. There are doubts on the part of management regarding the value of change until it is fully demonstrated. There are doubts about the wisdom of investing in costly new equipment when it is known that there is yet more modern equipment about to come on the market.

This lengthens the whole process and leads to two things. First, it provides the industry with the stimulus for even more and faster product development. But it also means a better opportunity and more time adjustment. That adjustment, I suspect, will be a continuing process over the next several decades, and perhaps indefinitely—who knows?

This raises a point which Keith Pavitt did not mention: the effects on society. I suspect that the effects on society are overestimated, here as in many other fields.

Our responsibility is to put all these issues in a reasonable perspective. We should stress at every opportunity the slow pace of the changes, and not talk so freely about revolution. We should be talking of the possibilities this technology offers for increased job opportunities over the long term. This is much better than talking of massive job losses occurring quite suddenly. Keith Pavitt did not suggest the latter, but I have heard it mentioned elsewhere. This now brings me to a rather different but related point.

At a meeting in Paris some years ago I had the temerity to suggest that certain advantages in the Japanese economy could stem from the fact that they employed substantially fewer social scientists than did many other countries. That remark created, I believe, the only laugh of the day on that occasion. But behind that comment lies my next question. We have heard that the educational system in Japan not only produces graduates in much higher numbers in relation to the population, than is the custom in Western countries, but that the number of engineers among these graduates is also proportionately much higher. However, the number of pure scientists, who would normally go into fundamental research is proportionately lower than is the case in the West.

When one seeks an explanation for the relative strengths and weaknesses of Japan in relation to the West, to ascertain why they are better at adapting other people's technologies than at innovating themselves, one should ask to what extent this difference in educational patterns plays a part? And is it true that in Japan a much higher proportion of the best brains go into engineering than is the case in the West? If it is true, why do these outstanding students prefer engineering and the pure sciences to the humanities?

This is linked to another point—the question of management. I have the impression that in Japan the engineer reigns supreme. We do not often find in Japan that managers have followed a route that is becoming so widely accepted in Europe, and has been largely imported from the USA. This consists of going to university to study almost anything, but preferably economics, and then proceeding to something called 'business studies' which they feel automatically makes them suitable for top management posts. I have a suspicion that in Japan this is a very unusual way to get to the top in industry. Instead, the way is to train in engineering and learn almost all the jobs in the factory before getting into the management stream. If that is the way, I would like to know what we in Europe could learn from such a route to the board room.

THE JAPANESE EDUCATIONAL SYSTEM AND THE ROLE OF THE ENGINEER IN THE MANAGEMENT OF FIRMS

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As an engineer, I am hesitant to accept all Mr. Silver's observations, for obvious reasons. But I believe he is essentially correct in relation to the teaching of social sciences in Japan. After World War II, apparently, almost all Japanese economists were Marxists, so the government did not rely on them, and instead used engineers to help in their economic planning. I must add, however, that I do not know whether this is an absolutely accurate picture. The point I would emphasize is that I believe nearly all Japanese companies oriented towards high technology products are now headed by people with an engineering background.

We can trace this back to the start of the modernization of Japanese industry, about a century ago. Technology and engineering were seen as a crucial part of this industrialization, modernization, Westernization—whatever you wish to call it. This was reflected in the education system, with both science and technology taught in the most practical way possible, with little emphasis placed on theory. In Europe during this period these subjects were still very much the domain of the academic world. Our Japanese system was, and still is, very much more oriented towards production, and using technology, rather than creating new sciences. Thus in the minds of most Japanese, engineering, management and even economics, are very closely related.

LOUIS DE GUIRINGAUD
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France

There seems to be some contradictions concerning the Japanese methods of management. Some of the contributors have suggested that the Japanese system of management is better, while others of our European colleagues have indicated that they believe there is little difference.

The experiences of the few Japanese companies established in Europe have been mentioned, and it certainly seems that they get better results in quality and productivity than those obtained by similar neighbouring European owned companies. But I do not think that evidence is conclusive. There is not one Japanese company manufacturing here in Europe on a scale sufficient to allow us to compare management styles.

Managing a plant of, say, a hundred or so employees is not really management. All small and medium sized enterprises do this, some well, others less well. The Japanese are clearly better in managing large companies and plants employing several thousands of people. In these cases, I am afraid it is not possible to transpose Japanese management styles either to Europe or to the USA. The techniques can be used as a basis, but we cannot imitate them. They are a consequence of historical events, Japan having jumped without transition from a predominantly feudal system to an industrial society in a fairly short time and with the old concept of allegiance of the serf to the sovereign and the duties of the sovereign to his vassals remaining to a large extent. They have found that their companies work more efficiently if the managers are more concerned, have a greater sense of duty to the welfare of both employees in the factories and the executives, and when the workforce fully support the objectives of the company. This is an historical circumstance, and neither Europe or the USA could possibly set up such a condition now. In Europe, the struggle of the working classes against their employers has, in many cases, left too many divisions between the two sides. That kind of struggle did not exist in Japan, which is reflected in the differences between the two societies, and their attitudes to work.

Concerning the point about engineers, when I was ambassador to Japan, I carried out a similar investigation to the one described by Keichi Oshima. All the information I collected tended to show that Japan really does produce more trained engineers and technicians than we do in Europe.

There is a second fact which shows the difference between Japanese engineers and their European counterparts. Young Japanese engineers graduating from the best universities are immediately put to work when they join a company on projects in the factories. Whatever degrees they might possess, whatever schooling they have had, they start to learn practical jobs right away. If they are in the steel industry, they will spend two years working in a blast furnace or rolling mill. They are then in direct contact with the supervisory staff and the workers, and during this period their wages are not much different from those earned by the lower supervisory staff.

In France, and I suspect the same is true for Germany and Britain, students with degrees from universities, polytechnics, or higher engineering schools just do not go to work in a rolling mill or start operating a blast furnace. They go straight up to the executive offices to work on administration, planning, or 'management sciences'. This is the difference and one has to understand it to explain why the Japanese management system apparently gets so much more from their workforce. The point is that when these young engineering graduates start rising in the hierarchy, they can still be in touch with the workforce and the supervisory staff. They have a much better appreciation of what the workers' problems are, they find it easier to talk to them and to enlist their cooperation with unaccustomed procedures or changes when these appear necessary.

Another aspect concerns retraining facilities. These engineers play a key role in the constant modernization process to boost productivity and efficiency. There is a constant exchange of views between the workers, managers and supervisory staff. This makes the engineer even more useful to the company. This is how Japanese engineers and managers are trained, and we in Europe have to admire it. This is why they are so good at improving on the patents they acquire, why they seem to be able to improve productivity and quality almost continuously.

At a somewhat lower level than that of the engineer, there is another very important difference between Japanese and French attitudes. This is the wide gap that exists between supervisory staff and workers. I suspect it is even deeper in other European countries, notably Britain, but it does not exist in Japan. The working team there is very much more cohesive, and this is a reflection of the importance of the supervisory staff—the foremen— in Japanese factories. It is very important to ensure this dialogue between workers and the company, and this consensus that we all admire in Japan but lack in Europe is a prerequisite, and one of the major factors, in the industrial success of Japan.

Of course this 'consensus' approach cannot be transferred as such, but we in Europe can draw lessons from it. First and foremost, it is clear that the training of engineers and the number of scientific and engineering graduates must be increased. We have made progress towards this in France over the last few years, but certainly not enough. There has been, and still is, a tradition of literary, legal and what I would call 'human' studies in Europe, which has led to erudite 'honest gentlemen'. It is those with this kind of education who gain access to power. This attitude is still being perpetuated. For example, in France, the National School of Administration is a 'nursery' of leaders of industry and government, and its curriculum is still broadly inspired by classical studies—humanities, law and economics. We have to accept this tradition, while pointing to it as an explanation for one of the fundamental differences between the Japanese and French systems.

There are other things we can learn from the Japanese about the training of engineers. We must ensure that our young engineering graduates get more practical experience early on in their careers, and make it easier for them to mix with workers and supervisors. Another lesson to be learnt is the importance of the cooperation and participation of shopfloor workers in decision making. Some tentative efforts have been made in this direction, perhaps more in Germany than in France or Britain.

There is another important factor that can explain the extra productivity achieved by Japanese companies, and I would call this the 'information factor'. As soon as something has been discovered or produced in Japan, it is published and disseminated. It would be interesting to know just why this is so. There is tradition, of course, but I would say that the attitude of the major industrial groups and huge trading companies plays an important part in this. They feel it is in their own interests to publicize, both internally and throughout the world, knowledge that they have discovered. They also feel it is in the interests of their customers.

Yet another dimension is the role of the government, through the auspices of the Ministry of International Trade and Industry (MITI). This has no equivalent in the world and its very name explains its objectives: industry must serve foreign trade. MITI itself encourages the dissemination of information on new discoveries in Japanese companies and government-funded research establishments. I am not sure this is the same for other administrations. Certainly it is not the case in France. Here, we have traditions that are exactly the opposite to this. The administration guards and retains information as a matter of course, and it is very difficult to break down such traditions. These then are the kind of lessons that we, the French, can learn from Japan.

MARC DUPUIS
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France

My first observation concerns the number of engineers in Japan. If you add up the number of students registered in engineering faculties, economics faculties or studying business administration, it comes to about 60 per cent. I do not have the exact figures, but I would say the distribution is 25 per cent in engineering, and the balance split about equally between the other two disciplines. The number of students studying pure sciences, on the other hand, is very low, about 5 per cent. The remainder study medicine, literature and pharmacy.

If we look at France, we find the position quite the reverse. Universities mainly produce scientists trained for pure research. Since 1958 they have started to train engineers, but the major responsibility for the training of our engineers rests with the Higher Engineering Schools, and the places available at these is still low. The system is geared to train an élite, and not to train large numbers of engineers for production management.

In the élitist centres of knowledge in Japan, such as the former Imperial University or the private universities, the number of students in the faculty of technology is much higher than the number of students studying sciences. This is due to the general attitude that for a young Japanese student, it is considered quite as brilliant and glorious to be a technologist as to be a scientist. This is not the attitude in France, which is that intellectually, pure knowledge will always prevail over good technology.

Now I wish to make an observation about the debate concerning the evolutionary or revolutionary nature of electronics. In France, we are getting quite used to reading in newspapers and the technical press reports of what is happening in Japan. They invariably give the impression that a revolution has in fact occurred there and that the Japanese are far ahead of Europe in technology. I have lived a great deal of my life in Japan, and I was always struck with the fact that the introduction of electronics in Japan has been a rather subtle process. In Europe during the 1970s, the first impact of electronics was its use in data processing. Thus, the French were trying to find high-powered tools for scientific calculations and to use computers to solve elaborate management problems. Conversely, in Japan the first application of computers and data processing was for process control; for improving the efficiency of chemical and manufacturing plants and for data transmission. Data transmission was taken up enthusiastically by many Japanese companies. One of the first major applications for the man in the street was for booking airline or theatre tickets and for banking. It then spread further and further.

The point I wish to make is that electronics was developed in Japan with a social purpose in mind. In Europe, I am afraid, as with education, we approached the whole business with an aristocratic, intellectual, somewhat highbrow outlook. The application of technology has always been much more pragramatic in Japan, and oriented towards applications with a strong social purpose. Of course, Europeans and American companies often say the same: that the products they have developed are primarily for the good of society —but I wonder whether this is not just an advertising gimmick.

ALEXANDER KING
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The question of 'strength' and 'weakness' is an extremely important topic to consider from the point of view of both sides, if we really are talking about two sides. The OECD countries have very many examples of these differences and there are many important cultural differences between the countries of the OECD. The point made earlier, that the Europeans were good at innovating and the Japanese better at applications, has of course been related to the European and American situations, right from the time of the World War II. I remember very well making similar comparisons at that time between the UK and the USA, showing that for every basic research worker in the USA, there were 2.5 people involved in applied research and development. The figures quoted for the UK were an unfavourable ratio of 1.1 engineer or applied scientist for every scientist doing basic research.

This meant that during the war, we in the UK had all kinds of bright ideas, most of which, even the military ones, were only exploited in the USA. Since then, this pattern has been inherited by Europe as a whole, and the American virtues and advantages seem to have passed to the Japanese.

It seems obvious to me that cultural factors in technological developments and innovations are extremely important, and we have not given nearly enough attention to them. I am sure that the Japanese, with their lack of interest in sociology, have not done so well in that field. However, I should add that the social science scene in Japan is of great interest to me. A few years ago, I was a member of a small delegation from the OECD which spent a short time in Japan studying that country's policy towards the social sciences. We were astonished to find that although the number of post-graduate degrees in subjects like sociology, anthropology, political sciences and economics was fairly high, it was completely overshadowed by the number of post-graduate students studying the sciences and engineering. This is obviously reflected in the realities of economic life.

One must also remember that in Japan there is a tremendous respect for the generalist, in government service, in industry and in all subjects, be they arts or sciences. A very important aspect of life there is the way young graduates enter industry and proceed by promotion and many internal movements up the managerial ladder. This is considerably supported by very good in-house training. We in Europe tend to put very much less emphasis on in-house training schemes.

To return to the role of engineers, another important difference concerns the 'status' factor. In Japan, and to some extent in Germany, the status of engineers in society is very high, and has been for a long time. The situation is quite the reverse in Britain where, partly for historical reasons, we use the word 'engineer' for anyone from a technician or plumber to a highly qualified, top level applied physicist. This has meant that engineers in Britain are at a disadvantage compared with accountants, lawyers and other professionals in the competition for top jobs in even the largest industrial concerns. These cultural aspects are, I believe, very important when we compare the industrial positions of Japan and Europe.

During the so-called 'industrial revolution' in Britain, the engineer had a very high status and was regarded as a leader in society, especially in Scotland, where much of the early industrialization took place. As scientists like Maxwell came along with important new discoveries, this attitude slowly dissipated and a certain academic élitism in favour of scientists at the expense of engineers crept into the system. This had a very detrimental effect on industrial development.

But what has this to do with the microelectronics revolution? I will explain, but first I cannot resist adding my own views on this debating point of 'revolution' versus 'evolution'. I think much of our difficulty here is one of semantics. The first industrial revolution was in fact also an evolution. It took decades to flower and the present development of microelectronics is just the same. What we see in industrial and social development, or evolution, is several discontinuities occurring from time to time. The invention of the steam engine was one such discontinuity. It led to a tremendous number of new activities and applications. In the textile industry, it started a whole new wave of mechanization; in mining, it made possible the draining of water from coal seams, leading to dramatic improvements in safety and productivity, and led to a host of new industries. Similarly, microelectronics is another discontinuity, with its universality and wide range of applications. I believe it is 'revolutionary' to the same extent as the invention and harnessing of the steam engine.

This first industrial revolution did not create social changes overnight. There were many difficulties, for example those created by the Luddites, who feared change and thus destroyed new machinery as it was being introduced. Social changes took many decades to work through, and I think the same is happening now. There will clearly be extremely profound social changes as a consequence of the microelectronics revolution, but we will not see them occur tomorrow.

My plea is that we should try and identify the possible social, economic and environmental changes, and prepare for them in advance, if that is possible. The first industrial revolution was horribly mismanaged and led to tremendous suffering, much of which was completely unnecessary. To take a very simple example: London was growing very rapidly as a consequence of people moving in from the country looking for work, and this led to very poor living conditions. The death rate rose tremendously during the first decade of the last century. The situation was even worse in some other early industrial cities like Glasgow and Manchester.

The situation could and should be very different today. If one considers cities that are expanding very rapidly today, such as Mexico City, one will see that much of the increase is coming from within the city itself. We have better conditions today, and more knowledge. We ought to be able to avoid many of the difficulties that occurred during that previous revolution, including the temporary problem of lack of employment. In Europe, too, there are bound to be many conflicts between the need for improving productivity and the possible effect of this on employment. But we should anticipate these problems now, and to a large extent alleviate them, by providing better social benefits and bringing about changes in the nature of society, which ought to take place in any case.

As regards the next stage in microelectronics, I feel it should concentrate much more on new applications and modifications to existing industry, rather than on a host of new innovations for the consumer. The new technical advances should aim to make industry more automated, manufacturing equipment 'intelligent' and devise new forms of transportation. This is bound to create social unrest, and I think Japan will be able to make the transition to this much more automated industrial society far better than the USA or Europe. The consensus approach that has been mentioned so often ought to help it overcome the inevitable social difficulties created, for it has conditioned the Japanese to accept changes smoothly and without undue social unrest. The Japanese are disciplined and hard working, they are marvellous at imitating and improving on the discoveries of others, and they have a paternalistic approach which allows society to absorb structural unemployment in a variety of ways. Japanese companies will, I am sure, lead the way in developing other electronic innovations, which will help them overcome any unemployment problems in the future. In Japan, it will be the companies, large and small, that will tackle the problem of jobs, while in Europe that will be left to governments to solve. The country's extremely harmonious industrial relations, and the good contacts and understanding between government and industry, also favour Japan.

In summary, I think Japan can look forward to a very prosperous future. We in Europe will have much to learn from Japan, but I fear we will be bogged down with too much internal dissension and discussion to solve the problems. I think that because of our historical traditions our cultural development will lead us in different directions from those taking place in Japan.

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