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OECD file

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LOCKHEED MARTIN

Norman R. Augustine
President

April 4, 1995

Dr. Jack Gibbons
President's Committee of Advisors
on Science and Technology
Office of Science and Technology Policy
Washington, DC 20500

Dear Jack:

In writing this letter, I suspect I am merely bringing some more coals to Newcastle; however, I do want to offer a suggestion for a study topic by the PCAST. Given the cutbacks in defense spending for research, the tendency of industry to move more in the direction of applied research (if any research at all) and the dependency of America's quality of life on competitiveness and that, in turn, on new technology, it would seem to me that a PCAST task force looking into the health of America's research universities is very much in order. This review would include the proper role for government in supporting thEse institutions.

It seems to me that this is a terribly important topic (I am not volunteering!) and one well worthy of PCAST attention. Although you have undoubtedly already seen the attached letter, I will send along another copy as it makes the point reasonably well.

I thought the meeting the other day was excellent and thoroughly enjoyed working on the Fissionable Materials Task Force.

With all best regards.

Sincerely,

Norman R. Augustine

/ljc
Attachment

March 13, 1995

We are writing as concerned industry executives to urge your continued support of a robust federally supported university research program. We recognize you face some tough choices as you deliberate and ultimately decide which federal programs merit continued support. We understand that priorities must be established. We strongly recommend, however, that you maintain a high priority on supporting the research efforts being carried out in our universities.

As you well know, America's leadership position in an ever-increasing globally competitive economy has been fueled by our technological prowess. Our universities, and the research programs pursued therein, have played a pivotal role in continually advancing our technical knowledge and know-how. Further they have produced the scientists and engineers who have provided the brainpower that allows American business and industry to operate and compete with nations and cultures throughout the world. The standard of living we enjoy today has, in large part, been made possible by our ingenuity and creativeness and our ability to continually advance and apply technology.

Our message is simple. Our university system and its research programs play a central and critical role in advancing our state of knowledge. Without adequate federal support, university research efforts will quickly erode. American industry will then cease to have access to the basic technologies and well-educated scientists and engineers that have served American interests so well. We, therefore, respectfully request that you maintain support for a vibrant, forward-looking university based research program.

W. W. Allen
W. Wayne Allen
Chairman & CEO
Phillips Petroleum Company

Norman R. Augustine
Norman R. Augustine
Chairman & CEO
Martin Marietta Corporation

John L. Clendenin
Chairman & CEO
BellSouth Corporation

Bob Eaton
Robert J. Eaton
Chairman & CEO
Chrysler Corporation

George Fisher
George M. C. Fisher
Chairman, President & CEO
Eastman Kodak Company

Louis V. Gerstner, Jr.
Chairman & CEO
IBM Corporation

J. T. Gorman
Joseph T. Gorman
Chairman & CEO
TRW, Incorporated

Gerald Greenwald
Chairman & CEO
United Airlines

George H. Heilmeier
George H. Heilmeier
President & CEO
Bellcore

Jerry R. Junkins
Jerry R. Junkins
Chairman, President & CEO
Texas Instruments, Incorporated

John McDonnell
Chairman
McDonnell Douglas Corporation

Randall L. Tobias
Chairman & CEO
Eli Lilly and Company

Roy Vagelos
P. Roy Vagelos, M.D.
Former Chairman & CEO
Merck & Company, Incorporated

John F. Welch
Chairman & CEO
General Electric Company

Edgar S. Woolard Jr.
Edgar S. Woolard, Jr.
Chairman & CEO
E.I. DuPont DeNemours and Company

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SCIENCE AND TECHNOLOGY POLICY

Review and Outlook
1994

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

— to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
— to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
— to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973) and Mexico (18th May 1994). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

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BILAN ET PERSPECTIVES 1994

Chapter 2

THE STRUCTURE AND INTENSITY OF INDUSTRIAL R&D EFFORTS

2

1. Introduction

This chapter examines in some detail the key trends in industrial expenditure on R&D in OECD countries over the last two decades. It focuses on the manufacturing sector, which accounts for the bulk of total industrial R&D expenditures and a large share of innovations, with emphasis on industries that are particularly trade- and technology-sensitive (the "friction-prone" sectors). The analysis centres on the five core countries of the Triad (France, Germany, Japan, the United Kingdom and the United States) and draws in Australia, Canada, Italy, the Netherlands and four Nordic countries, countries in which many of the fastest changes are occurring. The group is here referred to as the OECD-13.[1] The period covered extends from the early 1970s to the late 1980s, making it possible to discern trends and to see how sustainable structural changes have been and what the future trajectory is likely to be.[2]

2. The distribution of business enterprise R&D expenditures (BERD) between the manufacturing and service sectors

While the value added of industrialised economies largely originates in the service sectors, industrial R&D expenditures of OECD countries are heavily concentrated in manufacturing sectors. In the G7 countries (see Table II.28), for example, R&D expenditures[3] in manufacturing have consistently represented more than 70 per cent of total industrial R&D expenditures. In 1990, Germany and Japan had the highest proportion, with levels reaching 96 per cent. The United States, France, Italy and the United Kingdom followed, with manufacturing's share of BERD ranging between 87 per cent and 92 per cent. Canada had the lowest with 70 per cent.

The share of R&D expenditures carried out in the service sector increased, however, in most of the G-7 countries between 1973 and 1990. Canada in particular saw an increase of more than 10 percentage points in the proportion of industrial R&D expenditures represented by service sectors. In Canada and the United States, the service sector's share of industrial R&D expenditures more than doubled over the same period.[4]

3. The distribution of manufacturing R&D expenditures across 13 OECD countries

As Chapter 1 showed, the United States is still the largest contributor to manufacturing R&D, although less

Table II.28. **Distribution of total business enterprise R&D expenditures between manufacturing, services and other industrial sectors**

(per cent of total BERD expenditures)

	Manufacturing			Services			Other industries[1]		
	1973	1980	1990	1973	1980	1990	1973	1980	1990
Canada	84.1	79.3	70.3	10.9	14.3	27.5	5.0	6.4	2.2
France	93.2	93.1	92.0	5.3	5.6	6.8	1.5	1.3	1.2
Germany	91.8	93.2	96.2	2.9	2.4	3.0	5.3	4.4	0.8
Italy	86.2	88.6	88.9	13.5	11.4	10.8	0.3	0.0	0.3
Japan	95.2	94.9	96.1	4.4	4.5	3.5	0.4	0.6	0.4
United Kingdom	91.2	92.9	86.9	7.1	5.4	11.6	1.7	1.7	1.5
United States[2]	96.6	95.9	92.0	3.4	5.1	8.0	..	..	..

1. Agriculture, hunting, forestry, fishing, mining and quarrying.
2. For the United States, agriculture and mining are included in services.
Source: OECD, STAN/ANBERD database and STIU database, EASD, STI.

so than in the early 1970s. Japan has seen the largest increase in share over the past two decades, and the European Community has held a relatively stable share, albeit with significant internal shifts (Table II.29).

These general trends are confirmed at a detailed sectoral level (Table II.30), although some significant exceptions emerge. In 1973, out of 22 manufacturing sectors, the only four in which the United States did not have the largest share of the OECD-13 total were textiles and clothing, industrial chemicals, pharmaceuticals and ferrous metals. The EC-6 held the largest share in the first three, and Japan had the highest share of the OECD-13 total in ferrous metals. During the 1970s and 1980s, the United States lost shares in 18 of 22 industries, while Japan gained shares in all but two: shipbuilding and other transportation equipment. In 1990, the United States remained the most important performer of R&D in expenditure terms in the great majority of manufacturing industries, but Japan had substantially narrowed the gap and in fact surpassed the United States in five industries – rubber and plastic products, non-metallic mineral products, non-ferrous metals, non-electrical machinery and electrical machinery. The EC-6's shares remained relatively stable in most industries throughout the 1970s and 1980s. The only EC-6 country to experience significant movements was the United Kingdom, whose OECD-13 shares declined in all but pharmaceuticals, computers and other manufacturing.

When the 22 industries are grouped, according to their level of technological sophistication, into high, medium and low technology (see Annex 2) it becomes apparent that the greatest convergence between the BERD shares of the United States and Japan has occurred in the low technology group (Figure II.16). Between 1973 and 1990 the gap between the United States and Japan narrowed from 23 to four percentage points. Japan overtook the EC-6 in spending in the low technology group, and its shares are converging almost as sharply towards those of the United States in the medium as in the low technology group. The United States' lead on Japan was larger in this group in the early 1970s (46 and 17 per cent, respectively), and, although the distance has narrowed (36 and 28 per cent, respectively), the difference is still large. The EC-6's share in the medium tech-

Table II.29. **Manufacturing BERD shares across selected OECD countries**

(per cent of total OECD-13 manufacturing BERD)

ISIC	Industry	Canada		France		Germany		Italy	
		1973	1990	1973	1990	1973	1990	1973	1990
3000	Total manufacturing	1.0	1.3	6.5	6.5	9.8	10.9	2.2	3.1
3100	Food group	2.4	1.8	4.5	7.1	3.1	4.4	0.9	1.4
3200	Textile group	1.5	3.7	11.5	6.6	6.5	8.5	5.7	1.0
3300	Wood group	0.9	8.5	3.3	2.1	1.4	15.9	0.0	1.1
3400	Paper group	4.3	5.9	3.2	2.8	1.7	3.5	0.8	0.1
3500	Chemical group	1.0	1.2	7.9	7.8	14.8	13.5	3.4	4.0
3600	Non-metallic minerals	1.0	0.6	9.5	5.6	5.7	8.1	0.7	1.4
3700	Basic metals	3.4	2.8	3.9	6.5	10.1	6.4	1.3	3.4
3800	Fabricated metals	0.8	1.2	6.2	6.2	9.0	10.7	1.9	2.9
3900	Other manufacturing	1.3	2.9	3.9	3.4	0.2	2.6	4.7	0.3
	High technology	0.9	1.4	6.4	6.6	8.4	8.5	1.5	2.9
	Medium technology	0.9	0.8	6.6	6.5	14.1	16.6	3.6	3.5
	Low technology	2.0	2.4	6.6	5.9	5.1	7.7	1.6	2.6
		Japan		Nordic-4		United Kingdom		United States	
		1973	1990	1973	1990	1973	1990	1973	1990
3000	Total manufacturing	12.9	22.2	1.7	1.9	8.3	5.7	55.3	46.6
3100	Food group	20.1	32.4	4.0	3.9	16.8	7.8	16.8	35.5
3200	Textile group	27.8	49.8	1.7	1.8	21.8	2.9	21.7	23.8
3300	Wood group	12.0	27.0	4.2	5.4	4.0	1.6	72.6	37.0
3400	Paper group	24.9	28.1	8.8	8.8	5.4	4.3	49.1	44.4
3500	Chemical group	16.0	22.4	1.5	1.9	8.5	8.6	43.2	37.6
3600	Non-metallic minerals	23.6	42.6	2.7	2.1	10.3	3.1	43.9	34.7
3700	Basic metals	31.8	52.3	4.0	2.9	9.2	3.1	31.8	18.2
3800	Fabricated metals	10.6	20.3	1.5	1.7	7.9	5.0	60.3	50.5
3900	Other manufacturing	20.2	35.1	3.5	5.4	7.1	7.5	58.4	40.9
	High technology	8.9	17.7	1.1	1.5	8.6	6.5	62.5	53.5
	Medium technology	17.4	27.9	1.8	2.3	6.9	4.4	46.2	36.1
	Low technology	20.8	32.5	4.2	3.3	10.6	4.4	44.1	36.5

Source: OECD, STAN/ANBERD database, EASD, STI.

Table II.30. **Manufacturing BERD shares across industries within a country (1990)**

(per cent of total manufacturing BERD)

ISIC	Industry	Canada	Denmark	France	Germany	Italy	Japan	U.K.	U.S.	Nordic-4	EC-6
3100	Food group	2.5	7.6	2.0	0.7	0.9	2.6	2.5	1.4	3.7	1.7
3200	Textile group	1.3	0.4	0.4	0.3	0.1	1.0	0.2	0.2	0.4	0.3
3300	Wood group	1.5	0.4	0.1	0.3	0.1	0.3	0.1	0.2	0.7	0.2
3400	Paper group	3.5	0.7	0.3	0.2	0.0	1.0	0.6	0.7	3.6	0.3
3500	Chemical group	17.3	29.5	23.3	24.0	25.4	19.5	29.4	15.6	19.6	25.8
351 + 352 – 3522	Industrial chemicals	6.0	4.1	9.9	16.4	6.4	10.1	11.5	6.8	5.9	12.9
3522	Pharmaceuticals	6.8	24.1	8.1	5.8	15.4	5.8	15.9	5.8	11.6	9.7
353 + 354	Petroleum refining	3.9	0.0	2.2	0.3	1.3	1.0	1.4	2.2	1.1	1.4
355 + 356	Plastic products	0.5	1.3	3.1	1.5	2.3	2.6	0.7	0.8	1.1	1.8
3600	Non-metallic minerals	0.6	2.1	1.1	0.9	0.6	2.4	0.7	0.9	1.4	0.9
3700	Basic metals	4.5	0.7	2.1	1.2	2.4	5.0	1.2	0.8	3.2	1.7
3710	Ferrous metals	0.7	0.3	1.4	0.9	1.7	3.4	0.7	0.3	1.8	1.2
3720	Non-ferrous metals	3.8	0.3	0.7	0.3	0.7	1.6	0.4	0.5	1.4	0.5
3800	Fabricated metals	67.7	50.3	70.4	72.1	70.5	67.4	64.7	79.7	66.0	68.8
3810	Metal products	1.0	2.7	0.7	2.5	2.5	1.5	0.7	0.8	2.2	1.8
3820 – 3825	Non-electrical mach.	2.6	12.3	3.3	11.2	6.6	8.9	3.2	3.0	15.1	7.0
3825	Computers	9.9	3.5	3.7	3.6	7.3	10.1	8.5	12.8	4.1	4.9
3830 – 3832	Electrical machinery	1.5	6.2	3.4	8.2	7.8	11.2	4.4	1.4	7.2	6.6
3832	Communications equip.	31.8	9.2	24.7	18.7	13.5	16.3	22.4	16.5	15.5	20.1
3841	Shipbuilding	n.a.	3.2	0.1	0.1	0.6	0.2	0.1	0.0	1.3	0.3
3843	Motor vehicles	2.6	0.0	13.0	17.1	18.3	14.4	7.1	11.9	11.2	13.4
3845	Aircraft	13.2	0.0	20.0	8.9	12.1	0.9	17.2	26.5	3.8	13.1
3842 + 3844 + 3849	Other transport equip.	n.a.	1.6	0.4	0.1	0.7	0.3	0.0	0.6	1.0	0.2
3850	Instruments	1.6	11.6	1.1	1.6	1.0	3.8	1.0	6.3	4.7	1.4
3890	Other manufacturing	1.1	8.2	0.3	0.1	0.0	0.8	0.7	0.4	1.4	0.3
	High wage	42.4	31.8	57.0	52.0	60.8	42.3	61.6	66.0	46.9	55.5
	Medium wage	47.9	43.9	36.5	38.1	29.6	41.5	30.5	30.2	37.0	35.2
	Low wage	9.7	24.4	6.5	9.8	9.6	16.2	7.8	3.8	16.1	9.3
	High technology	64.8	54.6	60.9	46.8	57.2	48.0	69.4	69.2	46.9	55.8
	Medium technology	18.4	27.8	30.8	46.7	35.0	38.6	23.6	23.7	37.0	36.1
	Low technology	16.8	17.5	8.3	6.5	7.8	13.4	7.0	7.1	16.1	8.1
	Resource intensive	12.3	10.4	6.1	2.7	3.5	8.0	5.1	5.2	8.2	4.7
	Labour intensive	3.4	11.4	1.4	3.0	2.7	3.2	1.6	1.5	4.0	2.5
	Scale intensive	16.9	11.2	28.2	36.3	29.9	32.0	20.6	21.1	25.8	30.1
	Specialised supplier	35.9	27.7	31.4	38.1	28.0	36.3	30.0	20.9	37.8	33.6
	Science based	31.4	39.3	32.8	19.9	35.9	20.5	42.6	51.3	24.2	29.1

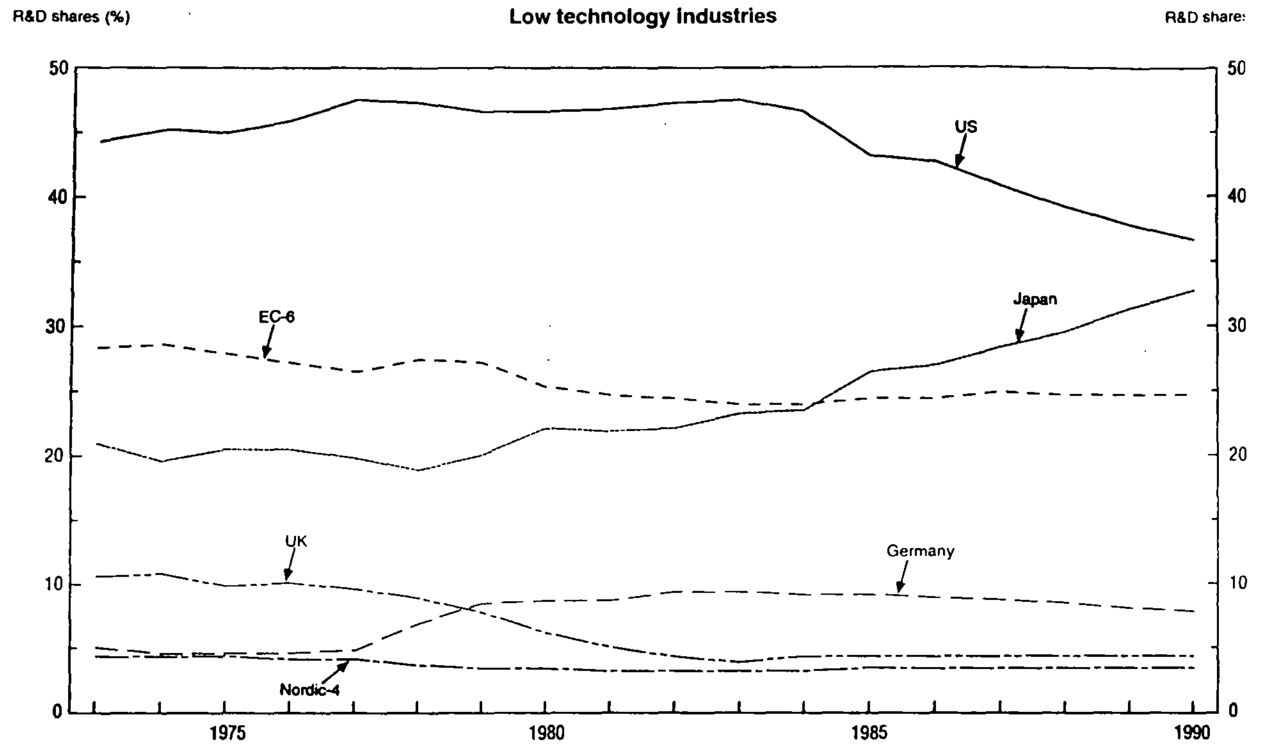
n.a. = not available.
Source: OECD, STAN/ANBERD database, EASD, STI.

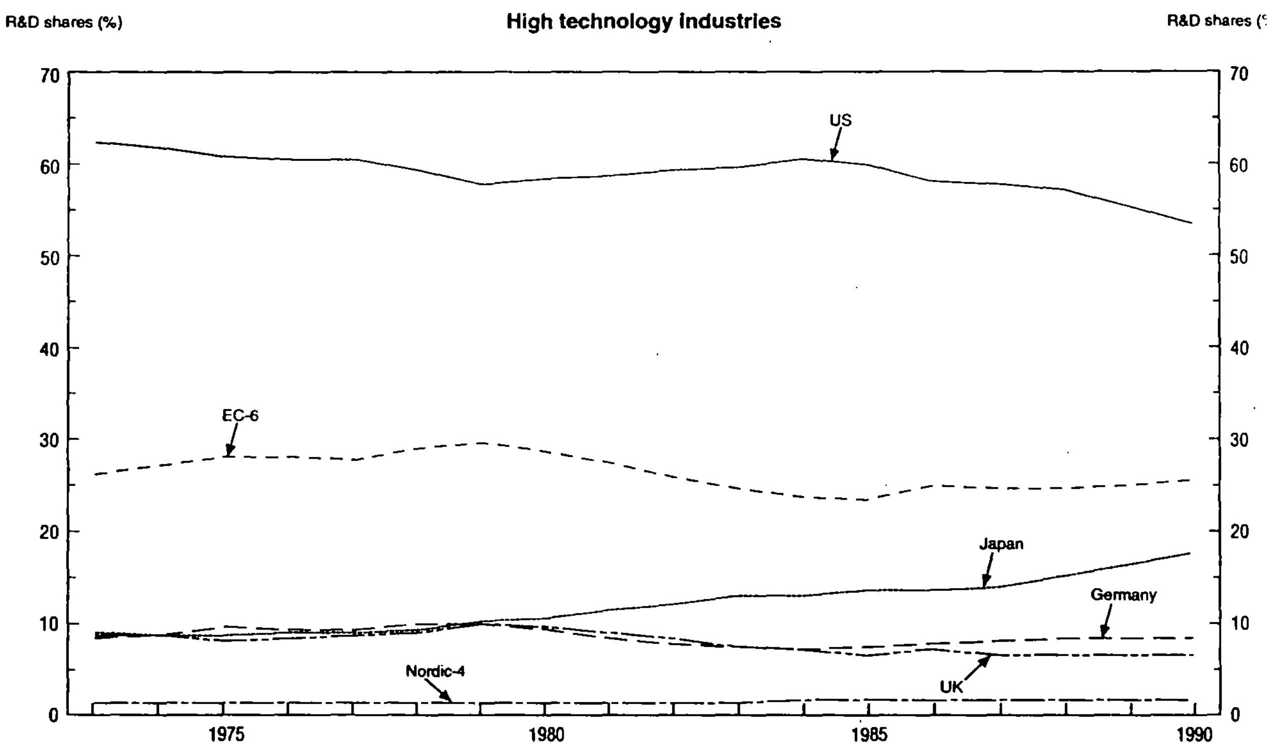
nology group remained constant, at about 33 per cent, due largely to Germany's consistent share of about 17 per cent.

The high technology group consistently has the highest level of cross-country variance in shares of R&D performed, largely because the United States has consistently dominated the category despite its falling position (Figure II.16). It had an extremely high 63 per cent of the OECD-13 high-technology total in 1973, and, although in 1990 its share had fallen to 54 per cent, this was still more than twice that of the EC-6 countries, which together are the second largest performer. Japan doubled its share, rising steadily from 9 per cent in 1973 to 18 per cent in 1990. Despite this increase, Japan's share of the total OECD-13 R&D performed by high-technology industries was still only one-third that of the United States in 1990.

Much of the lead the United States retains in the high technology group can be attributed to R&D carried out in the aircraft sector. In 1990, the United States accounted for 75 per cent of OECD-13 R&D performed in the aircraft industry, while the three other countries with significant R&D activities in this industry (France, Germany and the United Kingdom) held a combined share of 22 per cent.[5] Although Japan performed only 1 per cent of the OECD-13 aircraft R&D in 1990, it held significant shares in two other high technology industries, electrical machinery and computer and office machinery. Its share in the computer industry jumped from 7 per cent in 1970 to 23 per cent in 1990.

Figure II.16. **Manufacturing BERD shares across the OECD-13 countries**





Source: OECD, EAS Division, STAN/ANBERD database.

4. The sectoral composition of manufacturing R&D expenditures within countries

A comparison of the shares of R&D expenditures in various industries across countries gives a sense of relative magnitudes of R&D efforts. However, the very large shares held by the United States and Japan tend to overwhelm the smaller countries. Calculating shares of expenditure on total manufacturing (MANERD) for all component industries within each country reveals the industrial composition, and thus the specialisation, of each country's R&D effort (Table II.30). In general, manufacturing R&D is predominately clustered in aircraft, motor vehicles, communications equipment, computers and pharmaceuticals, which in 1990 accounted for 64 per cent of all OECD-13 manufacturing R&D. The largest share of the United States' 1990 MANERD (73 per cent) was concentrated in these five industries, while the four Nordic countries and Japan had the smallest shares with less than 48 per cent. The high concentration of manufacturing R&D in the United States is supported by the very high variance of R&D shares calculated across all manufacturing sectors (see Table II.31).[6] The EC-6 group had roughly the same profile as the United States, with over 60 per cent of its manufacturing R&D clustered in these five industries. Of the EC-6 countries, the United Kingdom had the highest share of manufacturing R&D in these sectors (71 per cent), while Germany had the lowest (just over 50 per cent).

Between 1973 and 1990, roughly one-quarter of the United States' manufacturing R&D was performed in the aircraft industry. This is by far the largest share for this sector in all the countries analysed and clearly establishes the aircraft industry as an area of R&D specialisation in the United States. Motor vehicles and communications equipment remained at relatively constant levels, with the share of the former hovering around 10 per cent and that of the latter ranging between 13 and 17 per cent. The computer industry saw the greatest gain, growing by 4.3 percentage points. These gains offset losses in rubber and plastics, non-electrical machinery, and particularly in electrical machinery, which fell from 9 per cent in 1973 to 1 per cent in 1990.

After the United States, France devoted the largest share (about one-fifth) of its manufacturing R&D to the aerospace industry. However, the communications equipment industry had the largest share of MANERD (consistently above 20 per cent, peaking at 25 per cent in 1987). Industrial chemicals (10 per cent in 1990) and pharmaceuticals (8 per cent in 1990) also had significant shares.

In the United Kingdom, the share of the aerospace industry fell from 26 per cent in 1973 to 14 per cent in 1988. Most gains in shares occurred in the communications equipment industry (from 15 per cent in 1973 to 22 per cent in 1990) and in pharmaceuticals (from 6 per cent in 1973 to 16 per cent in 1990).

In Germany, 60 per cent of 1990 MANERD is concentrated in industrial chemicals, non-electrical machinery, communications equipment and motor vehicles. The highest share was that of the communications equipment industry, ranging from 15 per cent to 19 per cent between 1973 and 1990. Although industrial chemicals still retained a substantial share of manufacturing R&D (16.4 per cent in 1990), it lost four percentage points over the period. Unlike most other countries, where the high technology industries carry out the highest percentage of MANERD, Germany's manufacturing R&D expenditures are evenly split between the high and medium technology industry groups (see Table II.30).

Italy's motor vehicle industry is by far the most important performer of manufacturing R&D, with 18 per cent in 1990. Pharmaceuticals follow, with about 13 per cent of MANERD from 1973 to 1988 and 15 per cent in 1989 and 1990. The aircraft industry has also become a key R&D performer in Italy, rising from 2 per cent in 1973 to 12 per cent in 1990.

The sectoral composition of manufacturing R&D in Japan is unusual, in that R&D expenditures are rather evenly distributed across industry. In 1990, Finland was the only country to display a lower cross-industry variance of MANERD shares (see Table II.31). Only communications equipment had more than 15 per cent of MANERD, followed by motor vehicles, which fluctuated between 12 and 14 per cent between 1973 and 1990. The computer and office machinery industry saw the greatest increase, jumping from 2 per cent in 1974 to over 10 per cent in 1990. In Japan, as in Germany and the Nordic-4 countries, less than half of MANERD in 1990 was performed in high technology industries.

The distribution of manufacturing R&D in the Nordic-4 group is also unusual in that the share in low

Table II.31. **Cross-sectoral variance of manufacturing BERD shares**

	1973	1990
Canada	26	45
United States	35	44
France	32	43
United Kingdom	37	41
Netherlands	35	37
Germany	36	36
Australia	30	35
Denmark	24	33
Sweden	21	31
Italy	n.a.	30
Norway	25	28
Japan	22	23
Finland	20	21

n.a. = not available.
Source: OECD, STAN/ANBERD database, EASD, STI.

technology industries is nearly twice the OECD-13 average (see Table II.30). Manufacturing R&D in low technology industries ranged between 27 per cent and 16 per cent between 1973 and 1990 in the Nordic-4 countries, against an average of less than 12 per cent for the OECD-13 area. In particular, the share of MANERD carried out by the shipbuilding industry was consistently seven to 11 times higher than the OECD-13 average and that of paper products five times higher.

5. Intensities of manufacturing R&D

5.1 Total manufacturing R&D compared with output

The preceding discussion did not take account of variations in the size of the manufacturing sector and its output trends over time. A comparison between MANERD and total manufacturing output reveals differences of intensity in the countries studied.

Among the countries with the largest economies, Japan has had by far the strongest growth in total manufacturing R&D intensity, especially since 1981, attaining in 1989 a level comparable to Germany's (2.5 per cent). By 1985, Japan had surpassed France and the United Kingdom. Yet its R&D intensity for manufacturing is only three-quarters that of the United States. Despite a slight decline from 1985 to 1989, the United States has consistently maintained the highest level of intensity among OECD-13 countries and was the only country in which this indicator exceeded the 3 per cent level (from 1985 to 1989).

Germany also showed an important rise in total manufacturing intensity over the period, although it was not as large as Japan's. Since 1983, when it overtook the United Kingdom, its intensity has been the highest among the EC-6 countries. The United Kingdom, which had displayed the strongest growth from 1977 to 1981, when it attained a 2 per cent level,[7] did not change appreciably during the 1980s. France, instead, showed steady growth in its total manufacturing R&D intensity and reached 2.2 per cent in 1989. The two remaining G-7 countries, Canada and Italy, had the lowest intensities of all OECD-13 countries in 1989, at less than 1 per cent.

Among the smaller countries included in the exercise, Sweden has by far the highest total manufacturing R&D intensity. From 1973 to 1989, Sweden's R&D intensity surpassed that of all other OECD-13 countries except the United States. Finland showed the strongest increase, with an average annual growth rate of 6.4 per cent. As a result, in 1989, Finland bettered the intensities of Australia, Canada, Denmark, Italy, and Norway, but not the Netherlands, which came second to Sweden in terms of R&D intensity. It could be argued that Finland's considerable growth was due to its low 1973 starting point, but all the countries it surpassed had intensities similar to Finland's in 1973. Denmark's total manufa turing intensity more than doubled between 1973 a 1989. In 1989, Australia had a total manufacturing inte sity of 1 per cent, with an average annual growth rate 14 per cent from 1983 to 1989.

5.2 Sectoral R&D intensities

These trends reflect changes in the compone industries. Although the distribution of R&D expend tures across industries reflects important sectoral diffe ences in countries' R&D effort, it fails to relate it to t economic structure of countries in terms of output. Whi one industry may hold the same share of R&D expend tures in two countries, it may represent very differe shares of production or value added of these countries. I this sense, the strong orientation of R&D expenditur towards certain sectors might be simply proportional the importance of these sectors in the industrial structu of countries. Similarly changes in the distribution R&D expenditures between industries over time migl merely reflect trends in the economic activities of t sectors concerned.

Data now available in the ANBERD and STA databases make it is possible to compare R&D intensiti among countries, measured as R&D expenditure as percentage of gross output, on an industry-by-indust basis over nearly two decades. An initial analysis of th R&D expenditure to production ratio can be made for th high, medium and low technology industry groups. Since these groups are formed on the basis of the ratio R&D expenditures to production in the OECD countrie on average, the R&D intensity is naturally highest in th high technology group and lowest in the low technolog group. However, Table II.32 shows that countries diffe significantly in how they allocate R&D effort across th high, medium and low technology industry groups.

In 1986-88, countries with a high total manufactu ing intensity such as Germany and Japan do not necessa rily display strong intensity in the high technology grou During that period, Japan's level of R&D intensity in th high technology sectors was below that of ever OECD-13 country except Italy. There is thus not neces sarily a strong link between high levels of total manufac turing intensities and an R&D-intensive high technolog sector. There is instead a stronger correlation between th R&D intensity of the medium technology group and th overall intensity of total manufacturing.[9]

An examination of individual industries confirm Japan's relatively low R&D intensity in what are tradi tionally considered high technology industries. In ever country but Japan, four industries (aircraft, computers communications equipment and pharmaceuticals) hav very high intensities. This clearly sets them apart fron other industries and unquestionably places them in th high technology group. In Japan, the R&D intensities o these four industries are significantly lower, and the dif

Table II.32. **Average R&D intensity ratios for all manufacturing sectors**[1]
Business enterprise R&D expenditure/production
(percentages)

Industry	France 1976-78	France 1987-89	Germany 1976-78	Germany 1987-89	Japan 1976-78	Japan 1987-89	United Kingdom 1976-78	United Kingdom 1987-89	United States 1976-78	United States 1986-88
Aircraft	14.1	15.2	30.1	22.6	5.9	7.6	14.9	9.7	18.7	21.4
Computers	13.0	10.8[2]	7.3	8.8	3.5	6.5	11.5	7.9	15.4	16.1
Communications equip.	10.3	11.8[2]	6.6	10.7	3.6	5.3	8.3	11.6	7.9	14.3
Pharmaceuticals	5.6	8.2	8.0	9.8	5.5	8.0	8.3	13.2	7.8	10.6
Instruments	2.2	2.6	2.2	3.1	2.6	6.3	1.6	3.1	5.6	5.1
Electrical machinery	1.8	2.1[2]	3.2	3.6	2.9	4.4	2.4	3.7	5.4	1.5
Motor vehicles	2.2	2.8	2.0	3.2	1.8	2.7	1.4	2.5	2.8	4.5
Industrial chemicals	2.1	3.1	3.2	4.2	2.3	4.4	1.7	2.6	2.0	2.7
Other manufacturing	0.4	0.4	0.1	0.7	0.8	1.3	1.5	1.2	1.3	1.1
Non-electrical machinery	0.6	1.0[2]	1.8	2.9	1.7	2.5	0.8	0.9	1.1	1.3
Rubber and plastics	1.8	1.7	0.5	1.1	1.2	1.5	0.3	0.4	1.3	0.8
Non-ferrous metals	1.0	0.7	0.5	0.4	0.5	1.5	0.4	0.5	0.7	0.8
Other transport equip.	0.9	2.8	1.0	1.8	2.0	4.3	..	..	1.0	1.3
Non-metallic minerals	0.7	0.7	0.3	0.8	0.9	2.2	0.6	0.4	0.8	1.4
Food group	0.1	0.2	0.1	0.2	0.3	0.6	0.3	0.2	0.2	0.3
Shipbuilding	0.2	0.3	0.3	0.9	0.4	0.6	1.1	0.1	..	..
Petroleum refining	0.6	1.1	0.2	0.3	0.3	1.0	0.4	0.5	1.0	1.5
Ferrous metals	0.3	0.7	0.3	0.5	0.5	1.0	0.5	0.5	0.4	0.3
Fabricated metals	0.3	0.3	0.2	0.8	0.5	0.6	0.2	0.4	0.5	0.6
Paper group	0.1	0.1	0.1	0.2	0.2	0.3	0.2	0.1	0.3	0.2
Wood group	0.0	0.1	0.1	0.4	0.1	0.3	0.1	0.1	0.2	0.1
Textile group	0.2	0.2	0.1	0.2	0.2	0.5	0.3	0.1	0.1	0.2
Variance	16.9	17.9	40.4	27.1	2.8	6.1	16.6	15.6	24.5	34.7

1. The manufacturing sectors are ranked in decreasing order of their R&D intensities according to the standard OECD definitions of high, medium and low technology industries.
2. 1986.

Source: OECD, STAN/ANBERD database, EASD, STI.

ference between them and other industries is much less marked. Japan has, on the other hand, higher R&D intensities than the other countries for almost all the medium and low intensity industries, as Japan's much lower cross-sectoral variance of R&D intensities confirms (Table II.32). Clearly, the broader distribution of Japanese R&D spending over industries is not a matter of industrial structure but marks a real difference in business behaviour.

Japan and Germany display an unequivocal increasing trend in R&D intensities from 1976-78 to 1987-89. In Japan, every industry has seen an increase in its R&D intensity. The strongest rises occurred in instruments, computers, pharmaceuticals, industrial chemicals and other transport industries. With an increase in R&D intensity of 2.5 percentage points, the pharmaceuticals industry has become the most R&D-intensive industry in Japan, surpassing in 1987-89 the aircraft sector. In Germany, R&D intensities fell in only two sectors (aircraft and non-ferrous metals). Despite a decline of seven points, the aircraft sector was still the industry with the highest R&D intensity ratio in Germany (1986-88); the strongest increases occurred mainly in the communications equipment, motor vehicles and non-electrical machinery sectors.

However, intensities did not grow in all industries and countries. In the United Kingdom, the R&D intensity of two high technology sectors (aircraft and computers) fell. The aircraft sector suffered the most important decline of all manufacturing sectors, dropping by five percentage points. At the same time, the R&D intensities of the communications equipment, instruments and pharmaceuticals industries grew significantly, making pharmaceuticals the most R&D-intensive industry in the country in 1986-88. With eight out of 22 sectors showing a fall, the United Kingdom has the highest number of sectors with declining intensities.

The United States displayed declines in seven industries, most significantly in electrical machinery, where R&D intensity decreased from 5.4 per cent to 1.5 per cent.[10] There were, on the other hand, notable rises in communications equipment, pharmaceuticals, motor vehicles, non-metallic mineral products and petroleum refining industries. The communications equipment sector showed the greatest percentage increase, rising from 7.9 per cent to 14.3 per cent, with an R&D intensity of 21.4 per cent in 1986-88.

In France, the aircraft industry also had the highest R&D intensity in 1986-88, at 15 per cent. France exhibited important increases in communications equipment, pharmaceuticals, chemicals and other transport industries, while the computer industry fell by two percentage points from 1976-78 to 1986-88.

These changes in R&D intensities raise the question of the adequacy of the standard OECD definitions of high, medium and low technology, which are based on a rank ordering of R&D intensities averaged across countries. As Table II.33 shows, the ordering of industries by R&D intensity gives nearly every country a different ranking. A list incorporating the latest data for all 13 countries will be found in Annex 2. It suggests that a breakdown into four categories, splitting the "medium" category into two, might be more appropriate.[11]

6. Alternative measures of manufacturing R&D intensities

The R&D expenditure to production ratio is a standard and traditional measure of R&D intensities and is suitable for comparisons between industries. However, it is inadequate for describing the R&D effort of the business enterprise or the manufacturing sector as a whole, because it takes no account of the differences in industrial structure from one country to another. If a country's economy is strongly oriented towards the extraction of natural resources and other low technology industries, it will probably have a relatively low R&D intensity for manufacturing as a whole. Yet this intensity may simply reflect an industrial structure in which industries that are not usually R&D-intensive have considerable weight. Similarly, if a country's high technology sectors account for a smaller than average share of output, its overall R&D intensity is also likely to be relatively low. This does not necessarily mean that the country is less technologically competitive. Its individual industries may have relatively high levels of R&D expenditure per unit of output when compared to competitors, but the industries themselves may not have heavy R&D expenditures. Using overall R&D intensities to rank technological performance introduces a bias against countries with favourable natural resource endowments and comparative advantages in the low technology industries and those that invest in R&D in sectors not generally considered as high technology.

To obtain a more complete picture of R&D efforts, several alternative measures of R&D intensity have been calculated (see Box II.2). They make adjustments for industrial structure and thus render countries more comparable. These new indicators were calculated using value added data, whereas the R&D intensities presented

Table II.33. **The five most R&D intensive industries in France, Germany, Japan, the United Kingdom and the United States**

(per cent BERD/Production)

	FRANCE				GERMANY			
	Average 1976-78		Average 1987-89[1]		Average 1976-78		Average 1987-89	
1	Aircraft	14.1	Aircraft	15.2	Aircraft	30.1	Aircraft	22.6
2	Computers	13.0	Communications equip.	11.8	Pharmaceuticals	8.0	Communications equip.	10.7
3	Communications equip.	10.3	Computers	10.8	Computers	7.3	Pharmaceuticals	9.8
4	Pharmaceuticals	5.6	Pharmaceuticals	8.2	Communications equip.	6.6	Computers	8.8
5	Instruments	2.2	Industrial chemicals	3.1	Industrial chemicals	3.2	Industrial chemicals	4.2
	JAPAN				UNITED KINGDOM			
	Average 1976-78		Average 1987-89[1]		Average 1976-78		Average 1986-88	
1	Aircraft	5.9	Pharmaceuticals	8.0	Aircraft	14.9	Pharmaceuticals	13.2
2	Pharmaceuticals	5.5	Aircraft	7.6	Computers	11.5	Communications equip.	11.6
3	Communications equip.	3.6	Computers	6.5	Communications equip.	8.3	Aircraft	9.7
4	Computers	3.5	Instruments	6.3	Pharmaceuticals	8.3	Computers	7.9
5	Electrical machinery	2.9	Communications equip.	5.3	Electrical machinery	2.4	Electrical machinery	3.7
	UNITED STATES							
	Average 1976-78		Average 1987-89[1]					
1	Aircraft	18.7	Aircraft	21.4				
2	Computers	15.4	Computers	16.1				
3	Communications equip.	7.9	Communications equip.	14.3				
4	Pharmaceuticals	7.8	Pharmaceuticals	10.6				
5	Instruments	5.6	Instruments	5.1				

1. In the case of communications equipment and computers, the R&D intensity is for 1986 only.
Source: OECD, STAN/ANBERD database, EASD, STI.

Box II.2

R&D intensity indicators

Simple R&D intensities are calculated as R&D expenditures for total manufacturing divided by the value added from total manufacturing.

Modified R&D intensities are calculated as the sum of R&D intensity for each sector of a country weighted by the value added share of total manufacturing held by each sector on average in 12 OECD countries*.

The *STIBERD* indicator is calculated as the sum of the R&D intensities across all sectors of a country which have been divided by the average R&D intensity calculated from 12 OECD countries, and then weighted by the value added share of total manufacturing held by the sector in the country.

* The calculation of the weights required complete sectoral coverage in each country. A lack of sufficient industrial coverage for France meant that only 12 countries instead of 13 were used to create the OECD weights.

in the previous section were calculated using production data (see Note 8).

6.1 Simple R&D intensities

When R&D intensities are calculated as expenditures on R&D performed in total manufacturing divided by value added from manufacturing, the intensities range from a low of 1.2 to a high of 9.8 over 1973-88 (see Figure II.17). This is the "simple" calculation. As for R&D intensity calculated with production data, the United States stood substantially above other countries. Its R&D intensity rose from a low of 6.1 per cent in the late 1970s to a high of 9.7 per cent, which it maintained through the late 1980s. Only Sweden approached the level of the United States, with an R&D intensity that increased steadily from 4.1 per cent in 1973 to 8.2 per cent in 1987.

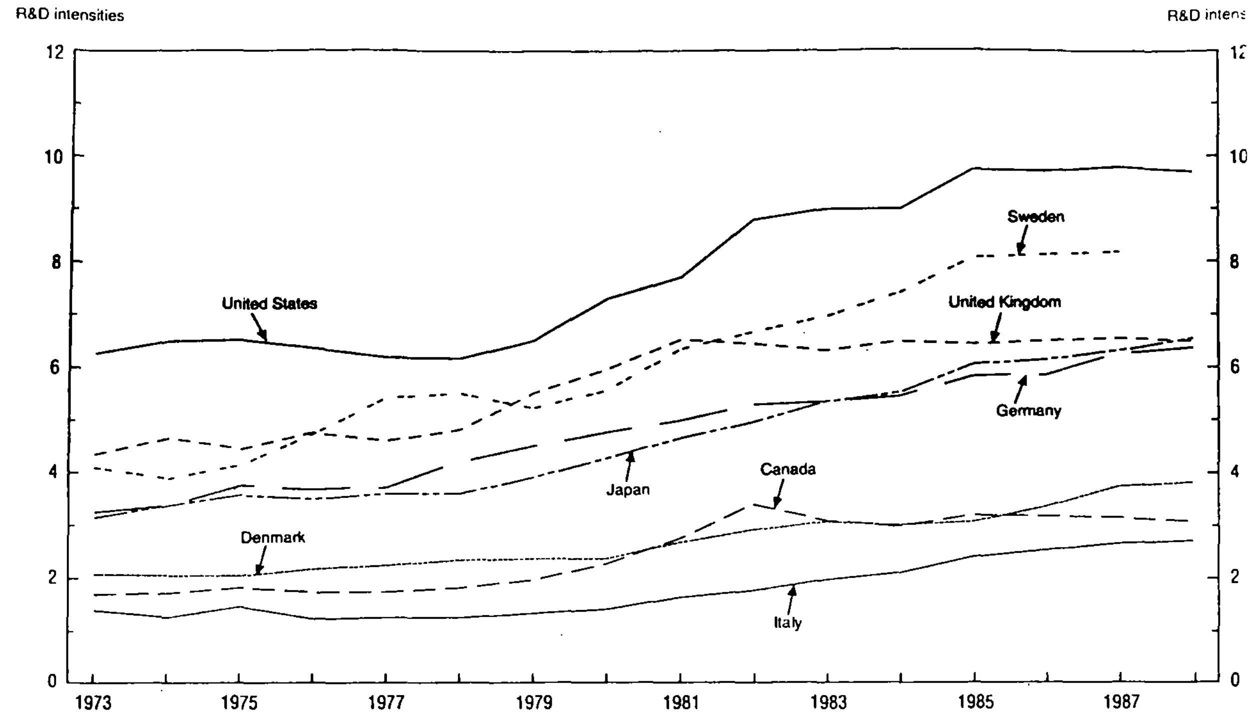
The eight countries for which R&D intensities could be calculated (due to data availability) form three groups on the basis of their levels of intensity (Table II.34); the United States and Sweden; the United Kingdom, Japan and Germany; and Denmark, Canada and Italy. These groupings remain virtually unchanged over the period considered, with one exception. In 1973, Sweden was roughly on a par with the second group but by the early 1980s started to draw closer to the United States. However, there were internal changes. The United Kingdom started the 1970s at the top of the middle group, even surpassing Sweden by the late 1970s, but showed little change after the early 1980s. This allowed Sweden to pass the United Kingdom in the 1980s, while Germany and Japan almost caught up with the United Kingdom in 1988.

6.2 Modified R&D intensities

These R&D intensities were first modified by calculating a common industrial structure for 12 OECD countries based on the shares of the average value added represented by each manufacturing sector. This common industrial structure (the average value added shares) was then applied to each national R&D intensity, and the new weighted R&D intensities were summed across all manufacturing sectors to attain a hypothetical total manufacturing R&D intensity for each country. The result is the total manufacturing R&D intensity that the country would have if it had the average industrial structure of 12 of the OECD-13 countries (a lack of sufficient coverage prevented the inclusion of France). In this way, countries that do not have a large part of their value added in the high technology industries but perform a relatively large amount of R&D in those industries will see an increase in their overall manufacturing R&D intensities. On the contrary, countries that have a large part of their manufacturing in high technology industry but do not necessarily perform significantly more R&D in these industries than most other countries, will see a decline in their manufacturing R&D intensity.

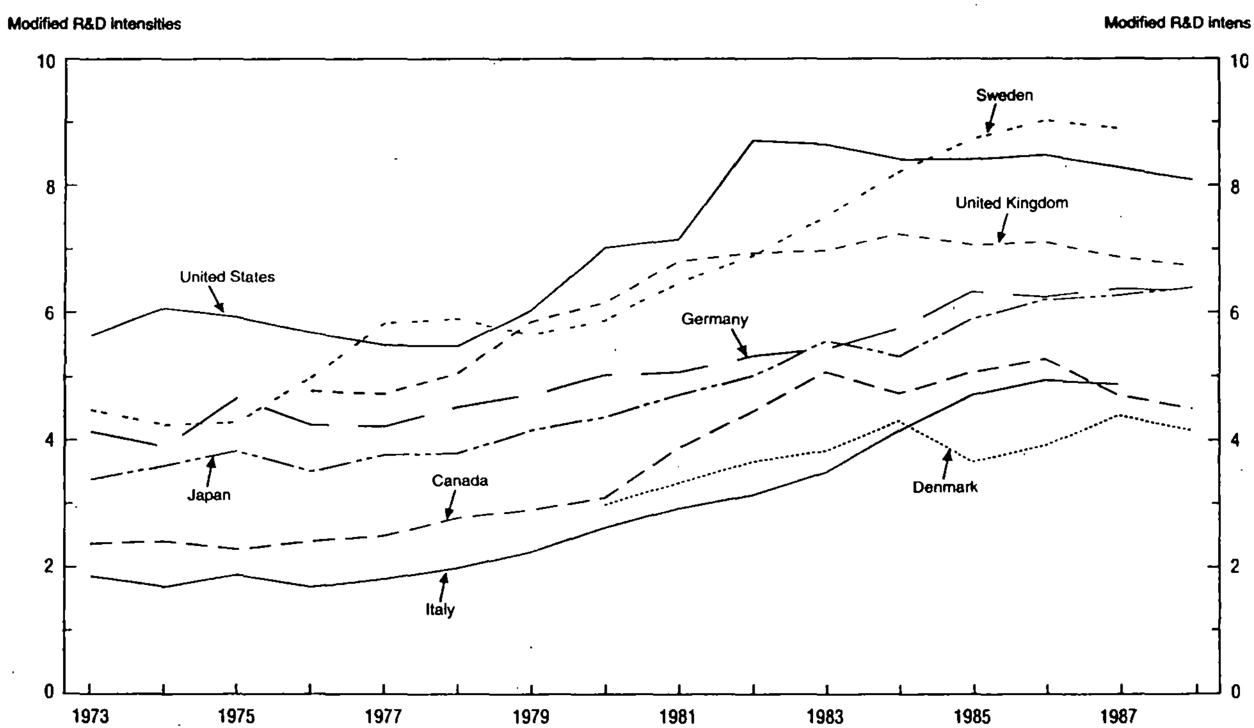
With these modified intensities, the general trends do not change significantly from those observed previously, but the countries are clustered more closely (see Figure II.18). In 1988, the variance across countries with the modified intensities was 2.4, whereas the variance was 5.3 for the simple R&D intensities (see Table II.34). Although the three country groupings can still be discerned, especially in the later years, the differences are much less significant, and in earlier years the country groupings are even less distinct. The United States still performed the largest amount of R&D relative to value added for most years between 1973 and 1988, but in

Figure II.17. **Original R&D intensities**



Source: OECD, EAS Division, STAN/ANBERD database.

Figure II.18. **Modified R&D intensities**



Source: OECD, EAS Division, STAN/ANBERD database.

Table II.34. **R&D intensities and STIBERD for 1973 and 1988**

	Basic R&D Intensity	1973	1988	Modified R&D Intensity	1973	1988	STIBERD	1973	1988
1*	United States	6.3	9.7	Sweden**	4.5	8.9	Sweden**	1.7	1.7
2	Sweden**	4.1	8.2	United States	5.6	8.1	Japan	1.1	1.3
3	Japan	3.1	6.5	United Kingdom	4.8	6.7	United States	1.2	1.0
4	United Kingdom	4.3	6.5	Japan	3.4	6.4	Germany	0.6	0.9
5	Germany	3.2	6.3	Germany	4.1	6.4	Denmark	0.8	0.9
6	Denmark	2.1	3.8	Italy**	1.8	4.9	United Kingdom	1.2	0.8
7	Canada	1.7	3.1	Canada	2.4	4.5	Canada	0.6	0.7
8	Italy**	1.4	2.7	Denmark	3.0	4.1	Italy	0.3	0.3
	Variance	2.3	5.3	**Variance**	1.4	2.4	**Variance**	0.2	0.1

* **Ranking is based on 1988 numbers.**
** 1987.
Source: OECD, STAN/ANBERD database, EASD, STI.

1974, 1975 and from 1985 onward, Sweden's modified R&D intensity was higher than that of the United States.

The United Kingdom's modified R&D intensity was slightly higher than both Germany's and Japan's; in 1979, it was almost on a par with that of the United States. The positions of Germany and Japan are very similar regardless of which R&D intensity computation is used.

In the third group, all three countries see significant increases in their intensities when the modified method of calculation is used. In 1988, Italy's R&D intensity is 80 per cent higher, Canada's is 46 per cent higher and Denmark's is 9 per cent higher. Canada takes the lead until the very late 1980s when Italy overtakes it, with a modified R&D intensity that grew twice as fast as its simple R&D intensity did. This is in sharp contrast to the "simple" ranking, where Denmark topped the list and Italy had the lowest intensities throughout the period.

These increases can be largely explained by the fact that these countries have the largest shares of manufacturing value added in the low technology industries: Denmark, 61 per cent; Italy, 59 per cent; and Canada, 58 per cent. Except for Sweden, the other countries have value added shares of below 50 per cent in low technology industries. Thus, when these countries' value added share in the high technology industries is increased by using an average industrial structure, their overall R&D intensity rises. This reflects the fact that the R&D intensities of some sectors are high in comparison to other countries, but the sectors carry relatively little weight in the country's industrial output. Italy displayed the strongest increase from the basic to the modified intensities because it puts a greater share of its R&D expenditures into the high and medium technology industries, which generate relatively little value added in the Italian economy.

6.3 STIBERD (structurally adjusted intensity of business enterprise R&D expenditures)

A further adjustment makes it possible to address the issue of whether the R&D intensity of certain industries in a country, particularly those accounting for large value added shares, compares favourably with the average R&D intensities of the same industries in other countries. This new R&D effort indicator was calculated by dividing the R&D intensity of each sector of a country by the average R&D intensity of the sector across the 12 OECD countries and then weighting these R&D intensities by the sector's share of total manufacturing value added in the country. These weighted relative R&D intensities were then summed across all manufacturing sectors to yield the country's STIBERD indicator.[12] This alternative measure benefits those countries where better than average R&D effort is performed in sectors that generate a large share of output. A high R&D intensity in a low technology industry is as beneficial to a country's STIBERD as a high R&D intensity in a high technology industry, if the low technology industry represents an important share of the country's manufacturing value added. Because the STIBERD indicator is an index, rather than a ratio, it is not directly comparable to the basic and modified indicators.

Country rankings change significantly when the STIBERD indicator is used in place of the simple or modified R&D intensities (see Figure II.19). All of the countries exhibited much more stability over time. This reflects the fact that countries tend to perform R&D in sectors that are important (large producers) in their economy. The three country groupings disappear, and Sweden stands well above the others. Its STIBERD ranges from 1.6 per cent to 2.0 per cent between 1973 and 1988, and even at its lowest level, it was at least 0.3 percentage points above every other country. It is, however, one of only three countries experiencing a decline in its (a loss of 10 share points), while Japan has advanced (a gain of nine share points). Nevertheless, after 17 years, the United States is still significantly ahead of the collective efforts of the EC-6 countries and Japan, which contributed 26 and 22 per cent of the 1990 OECD-13 total, respectively.

The narrowing of the differences in R&D performed by the manufacturing sector has been mainly concentrated in the low and medium technology sectors. For the former, the gap between the United States, Japan and the EC-6 has narrowed from 23 share points in 1973 to 12 in 1990; for the latter, it has gone from 28 points in 1973 to eight in 1990. In the high technology industries, it has dropped from 54 to 36 share points. However, the United States still carries out over half of the OECD-13's high technology R&D, double that of the EC-6, the next performer, whose share has stayed relatively stable at 25 per cent. By and large, this is attributable to the aircraft industry, a sector in which the United States conducts three-quarters of the OECD-13's R&D. The convergence in R&D spending has been due mainly to the fact that Japan has increased its effort at a faster rate than the United States and the EC-6.

In terms of the distribution of R&D across manufacturing industries, the countries show very different patterns of R&D investment. The United States and the United Kingdom tend to concentrate their R&D on high technology industries, while Germany puts a relatively larger share into medium technology ones. Japan is unique among the five largest countries in performing a relatively large share of R&D in low technology sectors, and it has increased its lead in this area, while increasing its share of R&D in many high technology sectors.

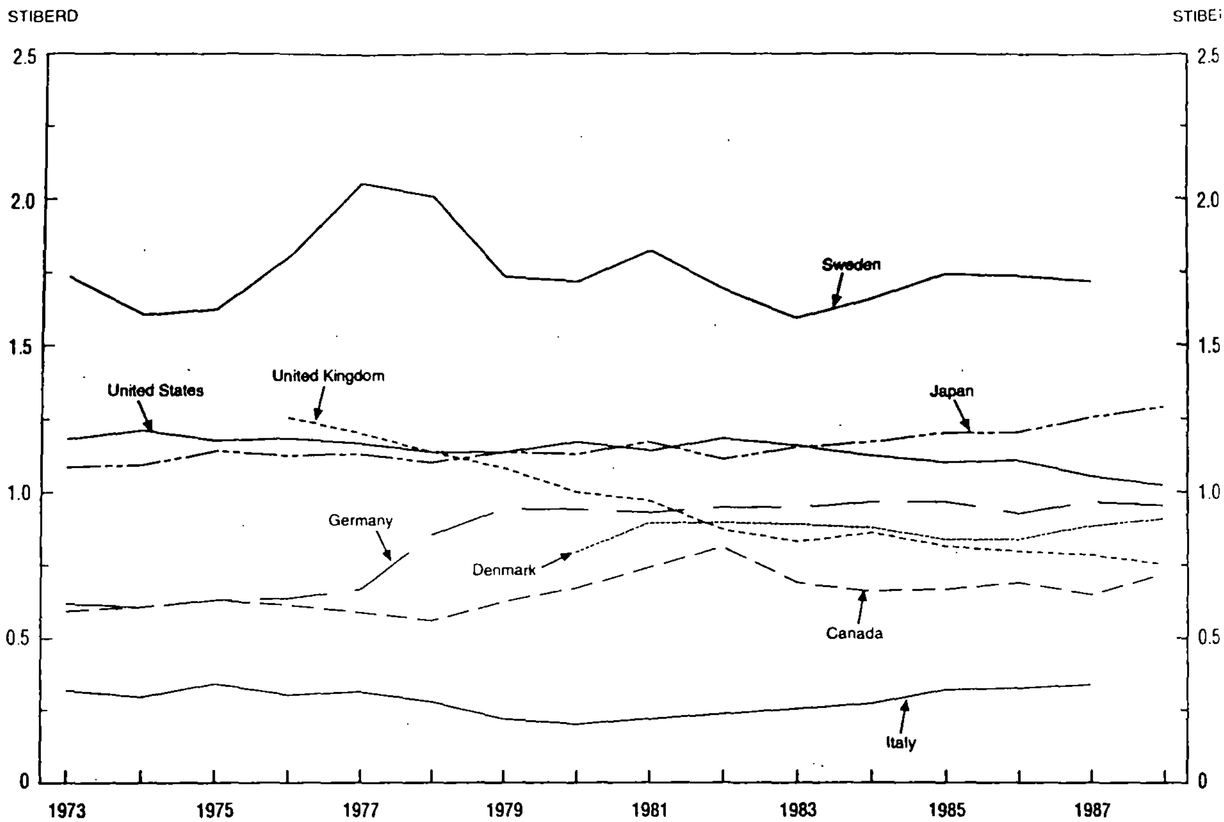
A slightly different picture emerges when the focus shifts to R&D intensity (R&D divided by output). The overall R&D intensity in manufacturing has not converged across the G7 countries; instead, the variance of intensity between countries grew by 74 per cent from 1980 to 1988. The sectors experiencing the largest increase in variance in cross-country R&D intensity are overwhelmingly "low technology" industries: textiles, non-metallic minerals, ferrous and non-ferrous metals and shipbuilding. The sectors experiencing a decline tend to be medium technology sectors such as rubber and plastic products, electrical machinery and motor vehicles. Cross-country variances in high technology industries were relatively stable and below the total manufacturing average.

This pattern of change can be attributed to a number of factors:

- R&D efforts have been put into sectors previously considered not to have a high level of technological sophistication. This could be due to the application of new technologies to sectors considered to be mature, such as the application of information technologies to the textile industry. Another factor could be the transformation of sectors such as non-metallic minerals, thought to be low technology, through discoveries such as fibre optics and high temperature ceramics.
- A cessation of new entrants or significant changes in the relative R&D intensity differences in high technology industries. In the 1970s, cross-country variances in the R&D intensity of the high technology group declined rapidly, suggesting the entry of new countries into sectors previously dominated by the United States. Examples include the entry of European countries into the aircraft sector via the Airbus consortium and Japan's targeting of the computer sector. By the 1980s, the initial declines witnessed during the 1970s had tapered off, leaving wide differences in effort but little change in the variances. This levelling of variances could be due either to diminishing returns to increasing the R&D intensity of a sector that is already very R&D-intensive or to a barrier to entry due to a sector's existing high R&D intensity.
- Lastly, one of the most likely factors is the simple fact that countries are performing R&D in sectors which are important to their economy, regardless of whether the sector is considered to be high-tech or low-tech.

This last explanation is consistent with the fact that only the STIBERD measure of manufacturing R&D intensity showed convergence in manufacturing R&D intensities between countries. Because this indicator measures whether or not countries have an above average R&D intensity in sectors that are important to their economy in terms of output, a reduction in the variance of this indicator suggests that countries continue to deepen their R&D effort in sectors in which they have a relative advantage – in effect, specialising further.

Figure II.19. **STIBERD (structurally adjusted intensity of R&D expenditure)**



Source: OECD, EAS Division, STAN/ANBERD database.

STIBERD over the 16 years, although this was very slight.

As for the simple intensity figures, Italy's STIBERD is the lowest. It was about 0.2 per cent in the early 1980s. This is because Italy is performing relatively less of its R&D in the low technology industries that account for 59 per cent of manufacturing value added, a higher percentage than every other country except Denmark. Yet, the distribution of Italy's R&D shares resembles those of Germany, the United Kingdom and the United States.

Because Canada and Denmark concentrate more of their R&D expenditures in the low technology sectors with large value added shares, they significantly improve their relative R&D performance when the STIBERD indicator is used. Canada is still behind every country except Italy for most of the period, but the distance is substantially narrowed. In the early 1970s, Canada's STIBERD was almost as high as Germany's, and in the early 1980s it approached the level of the United Kingdom. Its increase of 20 per cent over the 15 years was second only to that of Germany.

Germany's STIBERD increase of 54 per c allowed it to move from 0.6 to 0.9, almost level with United States, in 1988. The United States and Ja traded second place in the rankings for most of period. The United States held the lead more often in early years; but since 1984, Japan's STIBERD has b above that of the United States, reaching 1.3 in 1988. T United States' STIBERD was 1.0 in 1988, down fr 1.2 in 1973. The United Kingdom was the only ot country with a larger decline in its STIBERD, which from 1.3 to 0.8, reflecting significant reductions in R&D shares and intensities of the low technology ind tries, combined with a slight fall in the manufactur value added share in these industries.

7. Conclusions

The United States is, and continues to be, the larg performer of manufacturing R&D, with 46 per cent of OECD-13 manufacturing R&D in 1990. In overall ma facturing, its dominance of the early 1970s has weake

NOTES

1. Taken together, these countries, referred to as the OECD-13, were responsible for 96 per cent of all OECD BERD in 1991. They include all the highly R&D-intensive countries except Switzerland but none of the less intensive ones. The six EC countries included Denmark, France, Germany, Italy, the Netherlands and the United Kingdom. In 1991 they were responsible for 92.5 per cent of all EC BERD.

2. This assumes that the levelling off in industrial R&D in the early 1990s is a temporary phenomenon and does not mark a permanent change in its level and structure. The recent availability of the STAN (Structural Analysis) database [OECD (1992), *The OECD STAN Database for Industrial Analysis*, Paris] and the ANBERD (Analytic Business Enterprise Expenditures on R&D) database [OECD (1992), "Business Enterprise Expenditure on R&D in OECD Countries", OECD/GD(92)173, Paris] make it possible to construct many indicators at a detailed industrial level.

3. The R&D data used throughout this chapter are for total intramural expenditure on R&D performed in the industry concerned. Some of this expenditure may have been financed by other sources, such as government.

4. The emergence and growth of service industries, such as software development, engineering and scientific services, telecommunication services and financial services, go far towards explaining this increase. However, the increase in the share of industrial R&D expenditures (BERD) attributed to services is in some countries partially explained by changes in survey methods and classification techniques. In the United States, for instance, part of the increase is simply due to expansion of the survey coverage in the 1980s. See Pollak, M. (1991), "Research and Development in the Service Sector", *The Service Economy*, Vol. 5 No. 3, ed. by the Coalition of Service Industries, Washington, DC. Another example is the transfer between 1985 and 1986 in the United Kingdom of the Atomic Energy Authority (U.K.A.E.A.) from the government sector to the business enterprise sector. This classification change is responsible for most of the increase in the services' share of industrial R&D expenditures in the United Kingdom since 1985, as the Atomic Energy Authority, which is heavily involved in R&D activities, is classified in the services sector. Although service sector R&D is increasing and is probably under-counted, the bulk of business enterprise R&D is still clearly performed in the manufacturing sector.

5. This was probably due in large part to the magnitude of the defence and space projects initiated by the US Government, which funded nearly three-quarters of the R&D performed in this sector. See National Science Foundation (1992), *Research and Development in Industry: 1989*, NSF 92-307, (Washington, DC), Table A-4, p. 20.

6. Variance is a measure of the degree to which individual values in a list vary from the mean (average) of all the values in the list. The lower the variance, the less individual values vary from the mean, and the more reliable the mean. A variance of 0 indicates that all values in the list are equal.

7. As for other comparisons of indicators over time, this reflects trends in both the nominator and the denominator. Between 1970 and 1980 the UK share of OECD production fell markedly. See Table PSO1 in *Manufacturing Performance: A Scoreboard of Indicators*, OECD, 1994.

8. Gross output (production) has been used as the denominator of the R&D intensity indicator, but net output (value added) could also have been used. A sensitivity test was conducted to examine if the ranking of industries according to their R&D intensity varies when value added is used instead of production. Although the R&D intensities of industries calculated using value added were much higher than those calculated using production, the relative ranking among sectors did not change. Those industries that were most sensitive to the use of value added as opposed to production were petroleum refining, non-ferrous metals, ferrous metals and motor vehicles. This is because of the importance of intermediate inputs to these industries which are included in production data, but not in value added data.

9. A simple Spearman rank correlation indicates a correlation of 0.68 between the total manufacturing R&D intensity and the medium technology intensity; the same correlation with the high technology group is 0.38.

10. Some of this decline could be due to the fact that the United States data are strictly classified by enterprise, while elsewhere efforts have been made to convert data to an establishment or product basis. Because the US data are based on enterprises, a change in the classification of a large enterprise from one industry to another (for example, if General Electric was shifted out of the electrical machinery industry) might result in such a shift.

11. In a separate project, the OECD is analysing methods for categorising industries by technological intensity in greater depth.

12. Strictly speaking this is STIMANERD not STIBERD as it deals only with the structure of manufacturing industry.

Chapter 4

TECHNOLOGY AND TRADE PERFORMANCE

2

1. Introduction

In the 1980s, rapidly increasing economic globalisation greatly stimulated technological and commercial competition among the major industrialised countries. The radical changes of that period have resulted in constant renovation of production processes and in generalised organisational and technological innovation.

Since technology has become an important factor for competitiveness of countries (or, in competition among countries), it is useful to clarify the relation between trade and technology.

Section 1 of this chapter briefly recalls the results of a breakdown of manufacturing industries by R&D intensity (R&D expenditures/production), which is presented in Annex 2 and indicates certain characteristics of international trade in high technology.

Section 2 reviews this trade performance in the light of three indicators, including the relatively new "contribution to the balance". This indicator measures, in each country, the relative contribution of the manufacturing sectors to the total trade surplus or deficit. Thus, each country's trade performance is analysed for the various industry groups, classified by R&D intensity. This analysis makes it possible to identify the pattern of trade flows among the three principal zones of the OECD, with respect to the technology level of the products traded.

Annex 2 proposes a new breakdown of manufacturing industries in terms of the R&D intensities. This new breakdown is justified by changes observed in the 1980s, when the R&D intensities of four industries (aerospace, computers, electronics/components and pharmaceuticals), rose very strongly, and those of the automobile and chemicals industries also strengthened markedly.

This new breakdown also better reflects the evolution of international trade,[1] which slowed considerably in value terms during the 1980s by comparison with the 1970s. However, industries that were technologically more intensive progressed more rapidly than the others (see Table II.37).

Of the ten industries for which growth of trade exceeded the average (manufacturing industry total) in the period 1980-90, eight are in the high and medium-high intensity groups.

Table II.37. **Growth rates for international trade and value terms (1980-90)**

(per cent)

Total manufacturing industry	8
High intensity	12.4
Medium-high intensity	9.5
Medium-low intensity	5.7
Low intensity	6.6

Source: OECD, EASD, STI.

These figures are complemented by those set out in Table II.38, which gives the breakdown by technology intensity of manufacturing exports from the OECD area. In the 1980s the share of high technology exports rose by five percentage points, to the detriment of low technology.

Looking at the individual sectors, it is clear that the rise was mainly attributable to computer and electronics equipment exports, which almost doubled over the decade. It should not be forgotten, however, that the share of these industries and the others in the high technology group does not exceed 15 per cent of total exports from the OECD area, only slightly higher than the share of the automobile industry.

The figures show why the high technology sectors alone cannot make up for a trade balance deficit and, considering the volume of investment they need, why they have to find outlets abroad, even when they have large domestic markets.

Table II.39 shows the average growth rate in world trade by industrial sector in the 1980-90 period. The figures in Table II.38 show why the high technology sectors alone, despite their dynamism, cannot make up for a trade balance deficit and, considering the investment volume they require, why they have to find outlets abroad, even when they have large domestic markets.

Table II.38. **Average growth rate for world trade in value terms[1] (1980-90)**

1.	Computers/office machines	16.22
2.	Electronics/components	12.44
3.	Scientific instruments	11.19
4.	Automobile industry	10.39
5.	Pharmaceuticals	9.71
6.	Plastics	9.46
7.	Paper/printing	9.43
8.	Electrical machinery	9.32
9.	Aerospace	8.14
10.	Basic chemicals	7.96
11.	Wood, furniture	7.84
12.	Textiles	7.16
13.	Stone, clay, glass	7.16
14.	Non-electrical machinery	7.16
15.	Food, beverages, tobacco	6.39
16.	Fabricated metal products	5.32
17.	Non-ferrous metals	5.32
18.	Ferrous metals	3.06
19.	Shipbuilding	2.89
20.	Other transport equipment	1.66
21.	Petroleum refining	-1.47
Total manufacturing industry		8.04

1. As growth in international trade is calculated here in value terms the price trend is not taken into account. This may result in real growth being underestimated in some sectors where prices rose very little and especially in those where prices declined (*e.g.* computers or certain electronics products). On the other hand, export growth for sectors with above-average price increases have probably been overestimated.

Source: OECD, EASD, STI.

Table II.39. **Structure of manufacturing exports in the OECD area**

(percentages of total)

R&D intensities	1970	1975	1980	1985	1990
High intensity	9.9	9.1	9.9	13.7	15.1
Medium-high	26.3	27.5	29.4	32.5	32.6
Medium-low	26.9	28.6	26.2	22.9	21.9
Low intensity	36.9	34.8	34.5	30.9	30.4
Total	100.0	100.0	100.0	100.0	100.0
Sectors					
Aerospace	2.6	2.3	2.6	2.8	3.4
Computers	2.1	1.7	2.1	3.9	4.2
Electronics/components	3.9	3.9	3.9	5.6	6.0
Pharmaceuticals	1.2	1.1	1.1	1.2	1.4
Instruments	2.9	2.9	2.1	2.7	2.7
Automobile industry	10.9	11.4	11.5	14.0	13.8
Chemicals	8.9	9.6	11.6	11.5	11.4
Electrical machinery	3.4	3.5	4.2	4.2	4.6
Non-electrical machinery	14.1	15.3	12.5	11.1	11.8
Other	50.0	48.3	48.4	43.0	40.7
Total	100.0	100.0	100.0	100.0	100.0

Source: OECD, EASD, STI.

2. Trade performance and technological intensities

In this study, three indicators have been used to analyse the trade performance of countries and industries:

- the trade balance;
- comparative advantage (contributions to the balance);
- export market shares.

The "contribution to the balance" indicator (see Box II.3) has been used to measure the comparative advantage of the various sectors and assess each country's specialisation structure. This concept differs from "revealed comparative advantage"[2] in that it does not refer to the exports of the other countries of the area concerned but considers, at the same time, the effects of the exports and imports specific to each country.

It should be recalled that the theory of comparative advantage is not used to compare the performance of trading partners in different countries but to rank the different sectors in the same country, which would then find it in its interest to specialise in, and export the products of, those sectors where it has the greatest advantage and import products in those where it has the least.

The "contribution to the balance" indicator used in this chapter postulates that a sector's comparative advantage increases with its capacity to generate trade surpluses. In the absence of comparative advantages or disadvantages, the contribution of each sector to the trade balance should theoretically be proportional to its share in total trade. The existence of comparative advantages and disadvantages means that each sector's real balance differs from this theoretical balance. It is the difference between the theoretical and the observed balances which is measured by the proposed indicator.

If the three preceding indicators are examined together (see Table II.40), it is possible to give an initial assessment of the type of specialisation by each country and analyse its changes as its technology intensity evolves. In the past decade, some countries became more and others less competitive.

Germany, Japan and, to a lesser extent, Italy gained export market shares while maintaining an overall surplus in their trade balance. On the other hand, the loss in competitiveness observed in the Netherlands, the United Kingdom, the United States and to some extent in France is reflected both in export market share losses and in trade deficits for the entire manufacturing sector.

Canada's and Sweden's performance differs in that Canada gained foreign market shares despite an overall deficit in its trade balance, while Sweden lost market shares, although it continued to obtain trade surpluses.

Box II.3

Comparative advantage: the contribution to the balance indicator (CONT)

Sectoral specialisation profiles can be worked out for a country's foreign trade, and the sectors with comparative advantages can be identified by using an indicator showing their contribution to the balance.*

When applied to a reference area (world, OECD, EC, etc.), a given country and an industrial sector i, this indicator is equal to:

$$CONT_i = \underset{\mathrm{I}}{100 \cdot \frac{X - M}{(X + M)/2}} - \underset{\mathrm{II}}{100 \cdot \frac{X - M}{(X + M)/2}} \cdot \underset{\mathrm{III}}{\frac{X_i + M_i}{X + M}}$$

when X = exports and M = imports.

- Term I relates the balance for the sector i to the average for the reference area's (here, the world's) goods flows.
- Term II is the same indicator as I but applies to all trade in goods.
- Term III gives the share of sector i in the reference area's total trade.
- Assuming there is no comparative advantage or disadvantage for each sector i, the total trade surplus or deficit should be distributed among the various sectors proportionally to their respective shares in trade (theoretical balance). This indicator could also take the following form:

$$CONT_i = \frac{100}{(X + M)/2} \cdot \left[\underset{\Uparrow}{(X_i - M_i)} - \underset{\Uparrow}{(X - M) \cdot \frac{X_i + M_i}{X + M}} \right]$$

observed theoretical balance balance

A sector i then has a comparative advantage if its observed balance exceeds its theoretical balance. It is easy to show that this depends on the difference between the export/import ratio for the sector i and that for the entire economy (or manufacturing sector).

If the sector i's export/import ratio exceeds the total export/import ratio, this sector has a comparative advantage, independently of the value of the total ratio.

* This indicator was proposed by CEPII, France (G. Lafay). See: "Economie mondiale: la montée des tensions", *Economica*, Paris 1983.

2.1 High trade surpluses

It is the volume of their trade surpluses which separates Germany and Japan from the other countries. At the start of the 1990s, Germany's trade balance surpluses in manufactured products amounted to $106 billion and Japan's to $165 billion, as compared with deficits of $12 billion in France, $22 billion in the United Kingdom and $90 billion in the United States.

The medium-high intensity sectors accounted for most of Germany's and Japan's trade surpluses (automobile industry, electrical machinery and scientific instruments for Japan, chemicals and automobile industry for Germany) (see Figures II.26 and II.28). Trade deficits were recorded, however, by the two countries' low-intensity industries, particularly after 1986.

Japan showed its great adaptability to changes in the world economy by branching out quite soon into expanding sectors and gradually withdrawing from mature sectors. Japan is the only country to have doubled, in 15 years, its export market shares in high technology sectors without increasing the overall rate of manufacturing import penetration.

It was able to do so by withdrawing from specialisation mainly in the low technology sectors which were generating surpluses (steel, metal products, stone, clay, glass, etc.) so that domestic demand could be met without massive imports. But the withdrawal from sectors in deficit was very gradual and moderate (non-ferrous metals, basic chemicals, wood, furniture, textiles, foodstuffs, etc.).

The analysis in terms of comparative advantage (contribution to the balance) shows that Japan has firmly consolidated its position in the high and medium-high technology sectors either by reducing its disadvantages or strengthening its advantages. Pharmaceuticals and aerospace fall into the first group, while the second includes scientific instruments and especially computers and electronics components, as well as the automobile industry, which became Japan's strongest sectors at the end of the

Table II.40. **Trade performance (1980-90)**

Country	Trade balance					Comparative advantage				Export market sales				
	HT	MHT	MLT	LT	TOT	HT	MHT	MLT	LT	HT	MHT	MLT	LT	TOT
United States	+p	–	–	–	–	+	+	–	–	–	–	–	–	–
Japan	+	+	–	–p	+	+	+	–	–	+	+	+	–	+
Germany	+p	+	+	–	+	–	+	+p	–	–	+	+	+	+
France	–	+	–	–	–p	–	+	–	–	–	–	–	–	–
United Kingdom	–p	–	–p	–	–	+	+	+	–	–	–	–	–	–
Italy	–	–	+	+	+	–	–	+	+	–	–	+	+	+
Canada	–	–	–	+	–	–	–	–	+	+	+	+	+	+
Netherlands	–	+	+	+	–	–	+	+	–	–	–	–	+	–
Sweden	–p	+	+	+	+	–	–	–	+	–	–	–	+	–

Abbreviations:
HT: High technology intensity
MHT: Medium-high technology intensity
MLT: Medium-low technology intensity
LT: Low technology intensity
TOT: Total manufacturing industry
+: Positive
+p: Partly positive
–: Negative
–p: Partly negative
Note: In export market shares column, a positive sign means market share gains and a negative sign market share losses.
Source: OECD, EASD, STI.

1980s[3] (see Figure II.27). Moreover, judging by the breakdown of R&D expenditure in the various industries, technical advances have been more evenly distributed over the industrial sectors; also, as a result of high growth, low unemployment and a highly skilled labour force, industrial restructuring has been easier and has materialised sooner and on a sounder economic and social basis than elsewhere. But the recent recession, which particularly concerns industry, along with the rise in the yen, calls for further restructuring if productivity gains are to be stepped up and firms are to improve their financial situation. The relocation of more production units in countries with low labour costs could help to achieve these objectives.

An analysis in terms of comparative advantage shows that Germany's strengths are in industries with medium and especially medium-high R&D intensities. European Community countries account for most of its trade surpluses, while its position is slightly weaker on certain external markets (mainly Japan and the United States).

Germany's weaknesses are mostly in the low technology industries, which have recorded trade deficits. However, contrary to what has happened in Japan, these sectors have gained export market shares through improved competitiveness in the metal manufacturing, textile/clothing and paper industries. Specialisation has declined, on the other hand, particularly in two high-intensity sectors, *i.e.* computer/office machines and electronics/components industries. These two sectors also show trade deficits and their market shares are down (se Figure II.29).

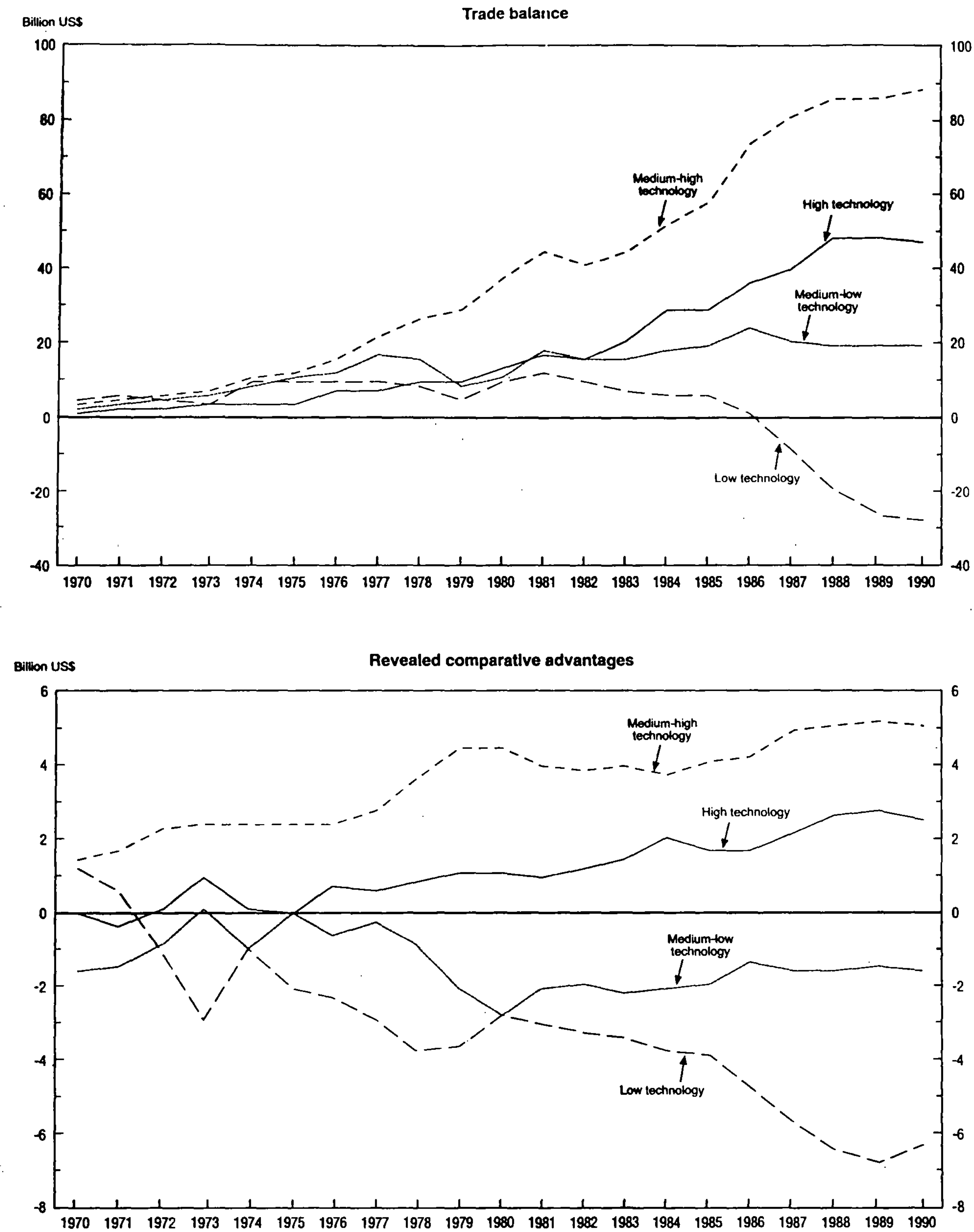
Despite these weaknesses, trade surpluses wer large because in over 40 per cent of cases, they con cerned high-growth sectors. And, despite the stead appreciation of the Deutschemark, German firms hav been able to adapt to changes in the world economy b making a considerable investment and innovation effor with the focus on "upmarket" (high value added though not necessarily high technology, products.

However, recent cost increases (higher wage shorter working hours over the year, environment-relate expenditures, reevaluation of the Deutschemark, etc have reduced competitiveness, particularly in the tradi tional sectors (steel, engineering, chemicals, car industr etc.), against a backdrop of economic recession. Suc being the case, an improvement in the productivity an profitability of firms will require new structural reform

2.2 *Weaker positions on external markets*

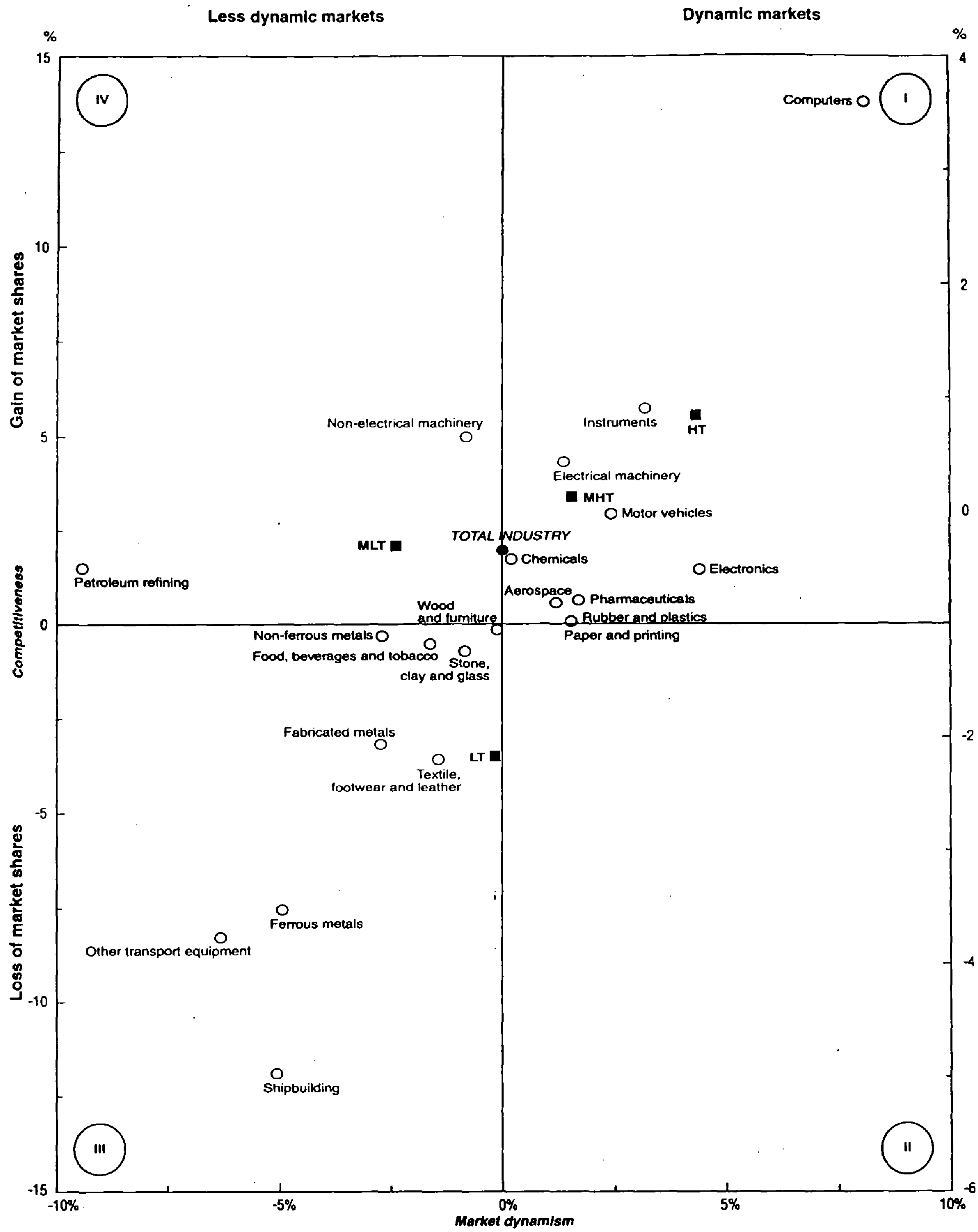
In the 1980s some countries lost market shar simultaneously in all four industry groups (higl medium-high, medium-low and low R&D intensity). Th was the case of France, the United Kingdom and tl United States. At the same time, these countries record trade deficits, particularly in the medium-low and lov intensity sectors in which, apart from a few exceptio (*e.g.* the agri-food industry in France and the Unit States), they have no comparative advantage.

Figure II.26. **Japan: trade balance and revealed comparative advantages**



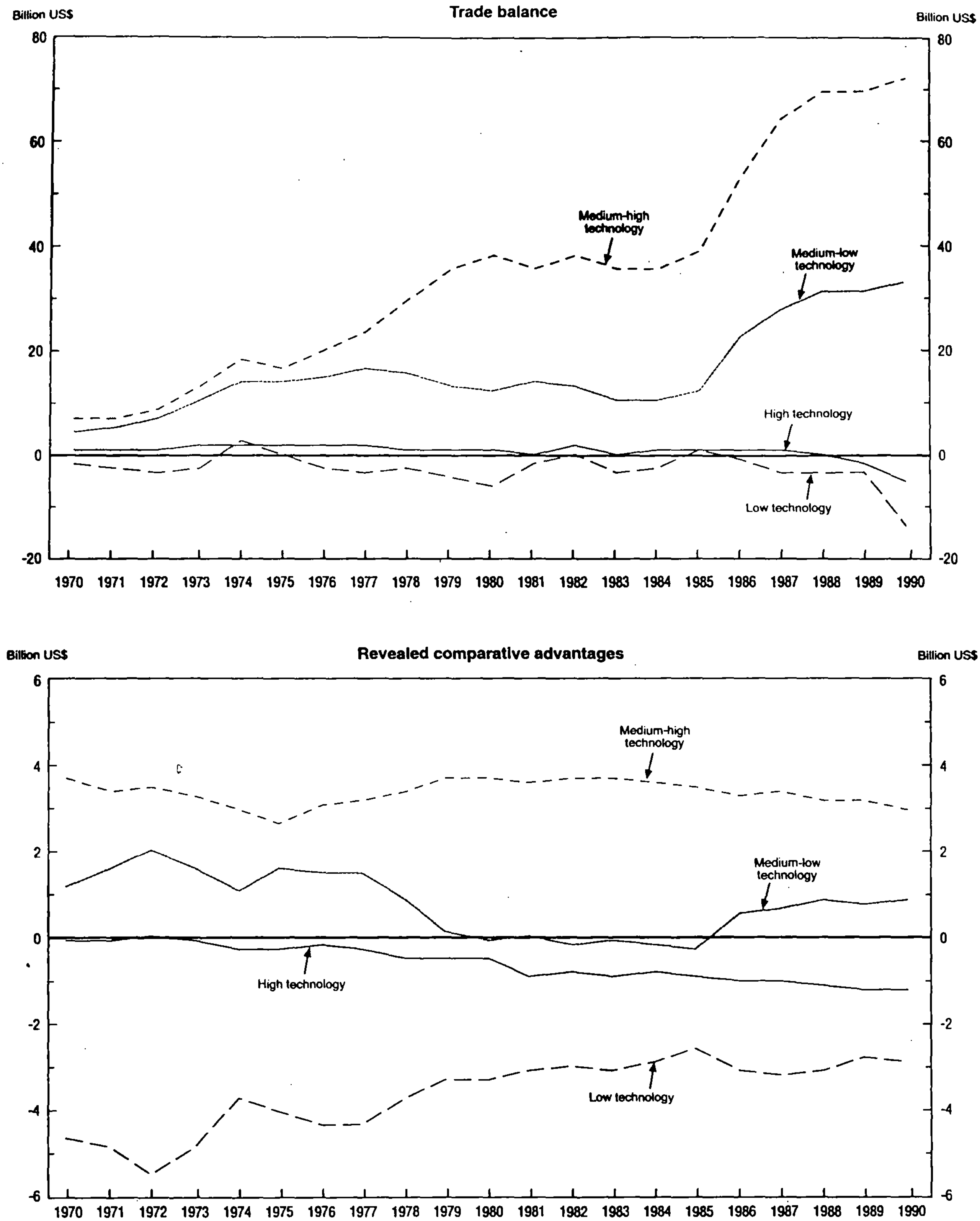
Source: OCDE, AES Division, STAN database.

Figure II.27. **Japan: positioning and competitiveness**
(1980-90)



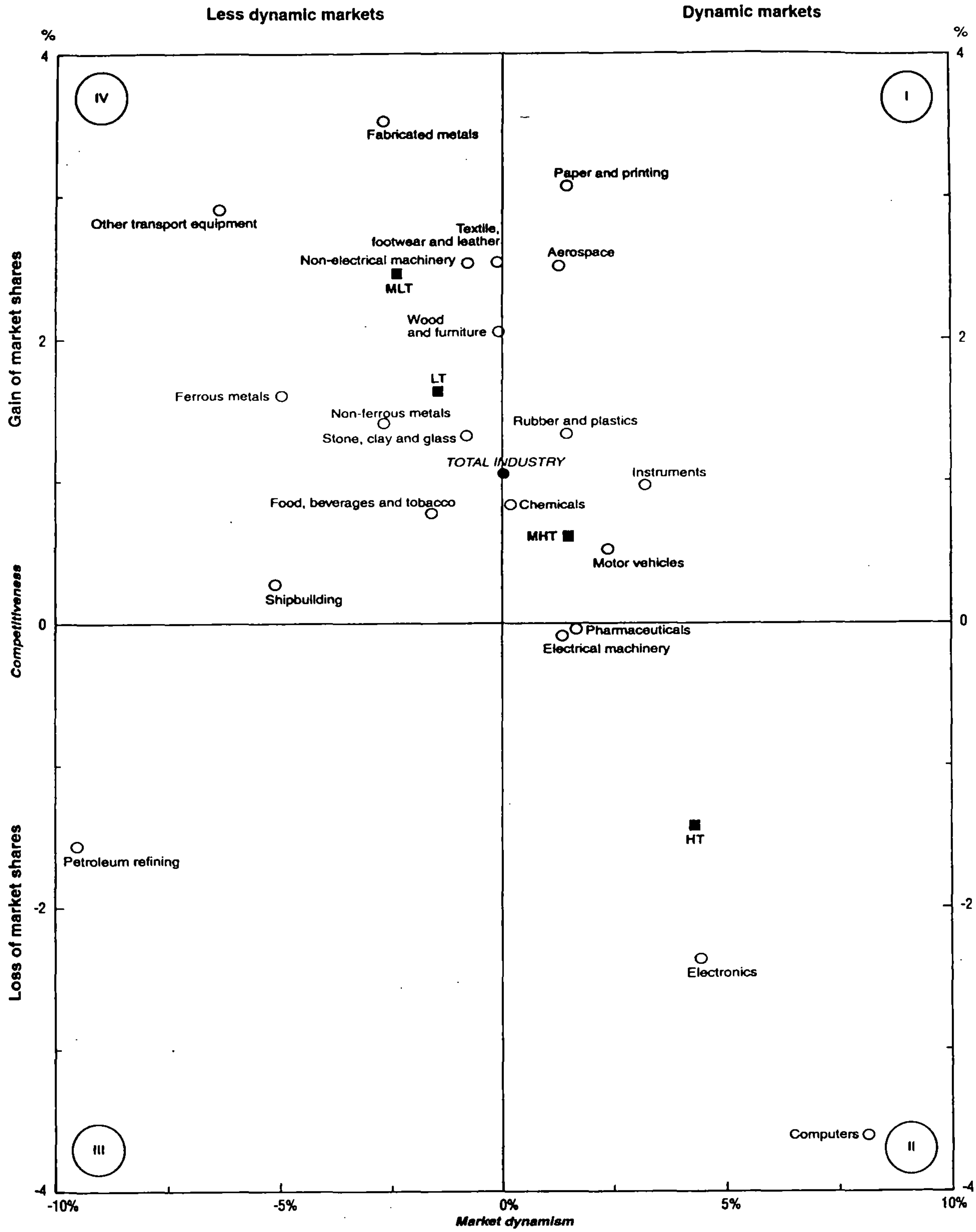
Source: OCDE, AES Division, STAN database.

Figure II.28. **Germany[1]: trade balance and revealed comparative advantages**



1. Former Federal Republic of Germany.
Source: OCDE, AES Division, STAN database.

Figure II.29. **Germany: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

Since 1981, the United States has seen a marked deterioration in its trade balance, but it is also the only country where the comparative advantage of high technology industries has been greater than that of all other sectors (see Figure II.30).

The adjustment of industrial structures has generally followed a pattern that is consistent with the innovation cycle. Specialisation has focused on technology-intensive sectors, such as the aerospace industry (main strength), computers and pharmaceuticals. These sectors are not, however, powerful enough to offset the declining competitiveness of the electronics sector and especially of those with a more standardised and rapidly diffused type of technology. A decline in competitiveness has been observed in the medium-high technology sectors, particularly in the automobile industry, which became the main weak point at the end of the 1980s, but also in the engineering industry and in electrical products (see Figure II.31). Although the chemical industry is still the second strongest US specialisation (as regards contribution to the balance), its position has also declined.

However, the depreciation of the dollar since the mid-1980s has boosted exports in some traditional sectors (wood, furniture, beverages, tobacco, steel, etc.) in which the United States has no comparative advantage. These exports are closely related to the exchange rate and could decline considerably if the dollar strengthened.

It seems, however, that restructuring in the second half of the 1980s helped to strengthen the industrial base of American firms and made it more dynamic. The first sign of this improvement was the return to a surplus in the high technology trade balance at the end of the 1980s (see Figure II.30).

Unlike the United States and even the United Kingdom, France specialises in medium-high intensity sectors (mainly chemicals, the automobile industry, plastics, other transport equipment, glass, aluminium) (see Figure II.32). Compared with its main competitors, French industry has, on the whole, fewer strengths:[4] in descending order: agri-food industry, automobile industry, chemicals and aerospace (Figure II.33).[5] This makes it less resistant and more dependent on the international business climate. In addition, its strengths are scattered widely across the industrial fabric, and the low surpluses they generate have a much less stimulating effect than the surpluses in Germany and Japan.

Yet efforts made by firms in recent years to step up productivity and reduce production costs have enabled French industry to recover some of its export market shares. In 1992, the trade balance also began to turn positive again.

In the United Kingdom, manufacturing industries' foreign trade declined substantially after 1982. This decline mainly affected the low technology industries, whose competitive position deteriorated more than that of their counterparts in other countries (Figure II.34). In absolute terms, the deficit of traditional industries was ten times that of the other branches of industry. This result may be ascribable to the substantial rise in the pound sterling in the 1970s and over a considerable part of the 1980s, which reduced the competitiveness of many mature industries, which are more sensitive to prices.

As a result, UK industry turned to specialisation in high technology and services. In these industries, aerospace and pharmaceutical industries continued to generate surpluses throughout the 1980s, but between 1980 and 1990 the aerospace industry lost half its market share (down to 10.7 per cent from 20.9 per cent). The computer and electronics industries, however, gained new market shares (see Figure II.35) and their specialisation improved.

The trade balances of the medium-high and to a certain extent medium-low technology industries have moved overall into the red, very largely because of the automobile industry, which at the end of the 1980s was the main weakness in UK specialisation.

2.3 Specialisation in low technology

Some countries have successfully specialised in low technology industries. This is particularly true of Canada and Italy. In Canada, only the low technology industries have had comparative advantages and generated surpluses since 1970 (see Figure II.36). In Italy, specialisation in these industries, which started later (at the end of the 1970s), is less marked than in Canada and coexists with specialisation in medium-low technology (see Figure II.38). It is probably this dual specialisation that gives Italy an overall surplus in its trade balance for manufactured products, while Canada has a persistent deficit.

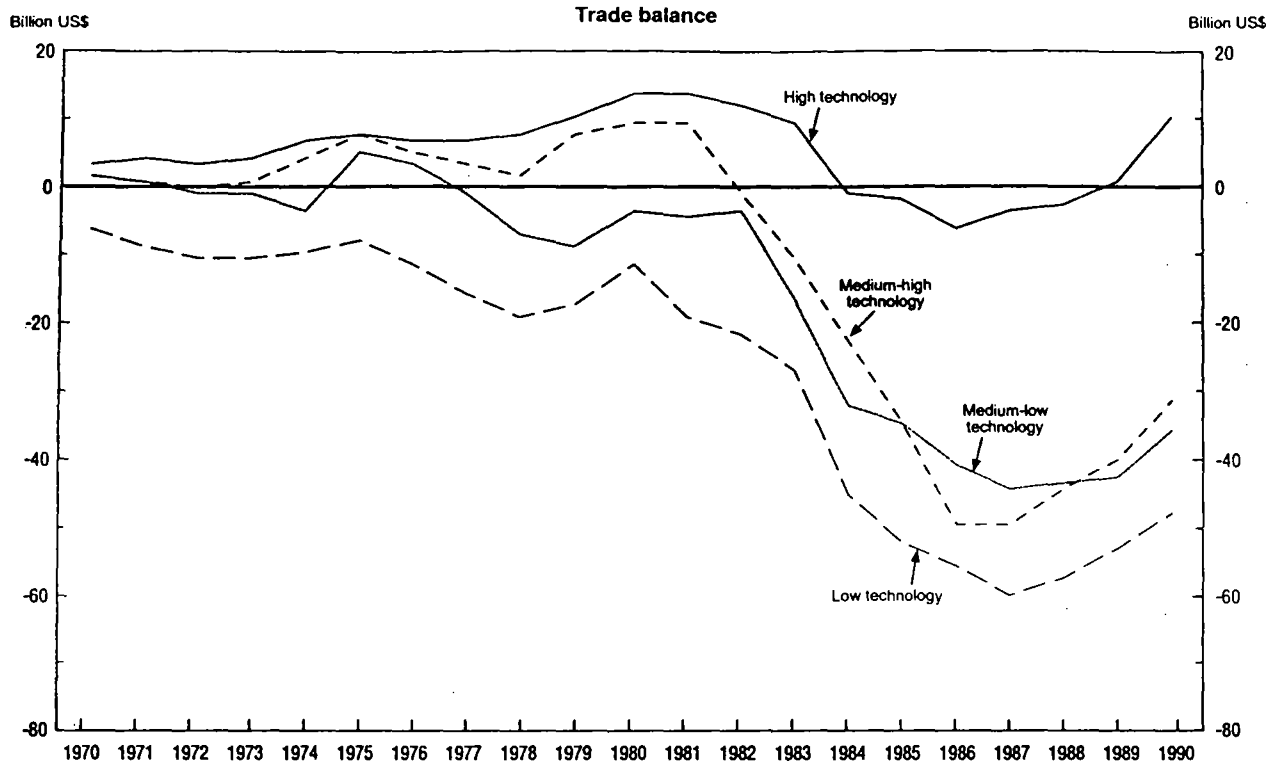
Italy's industry still specialises more in traditional sectors (textiles, clothing, footwear, leather, wood, furniture, metal products, etc.) which have gained market shares (see Figure II.39). At the same time, Italy has considerable comparative advantage in other sectors, such as non-electric machinery (the second-ranking product after textiles/clothing) and particularly in machine tools, but also in electrical equipment (domestic appliances) and in the rubber/plastics industry (although the latter has lost market shares).

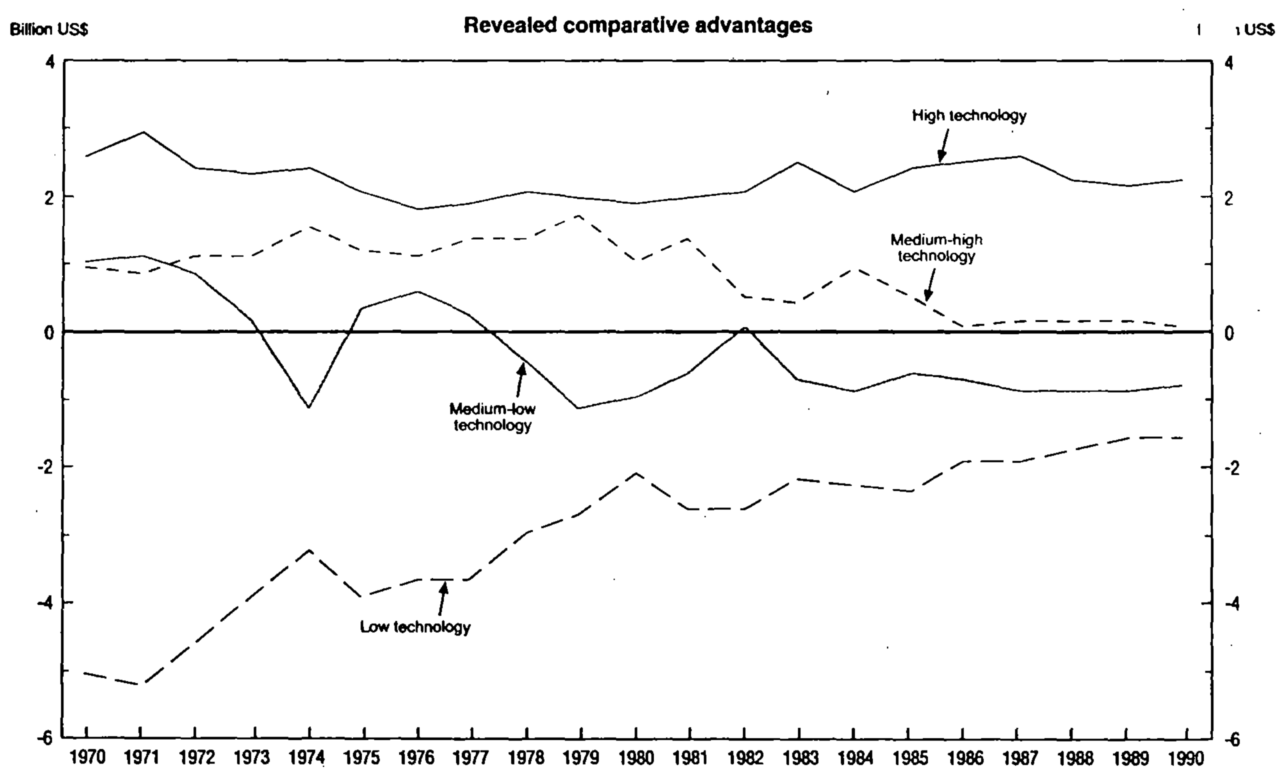
Italy's ability to move into market slots where other countries are less active has enabled it to obtain trade surpluses in the manufacturing field, especially in trade with the EC countries, including Germany.

Canada's situation may seem somewhat paradoxical since, despite the continuing trade deficit for manufacturing industry overall, the four industry groups (high, medium-high, medium-low and low intensity) all improved their market shares between 1980 and 1990 (see Figure II.37).

This paradox can be explained in two ways. First, in 1980, Canadian industry had lost 35 per cent of its market shares compared with 1970 (4.22 per cent against 6.44 per cent). Between 1980 and 1985 it recovered most

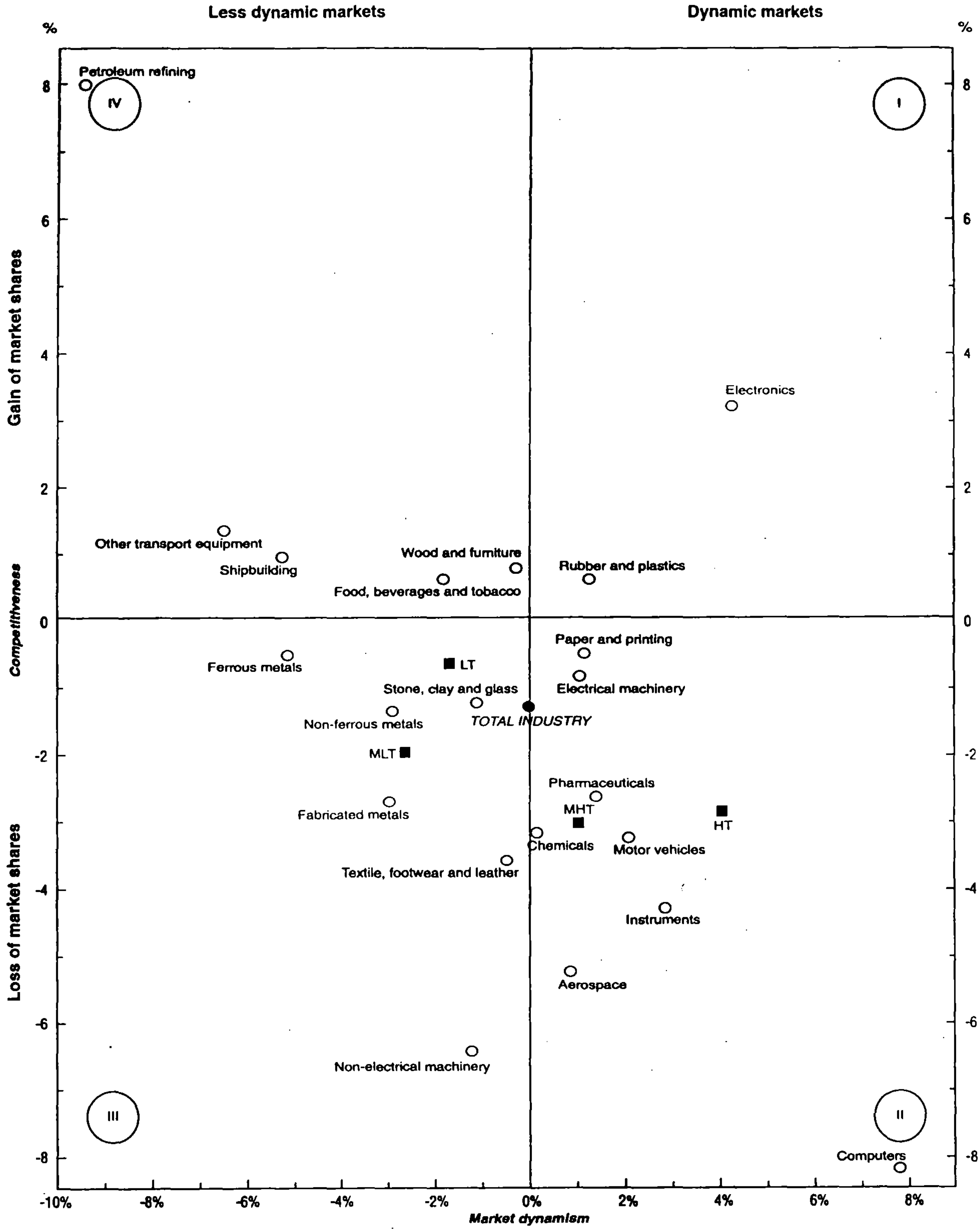
Figure II.30. **United States: trade balance and revealed comparative advantages**





Source: OCDE, AES Division, STAN database.

Figure II.31. **United States: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

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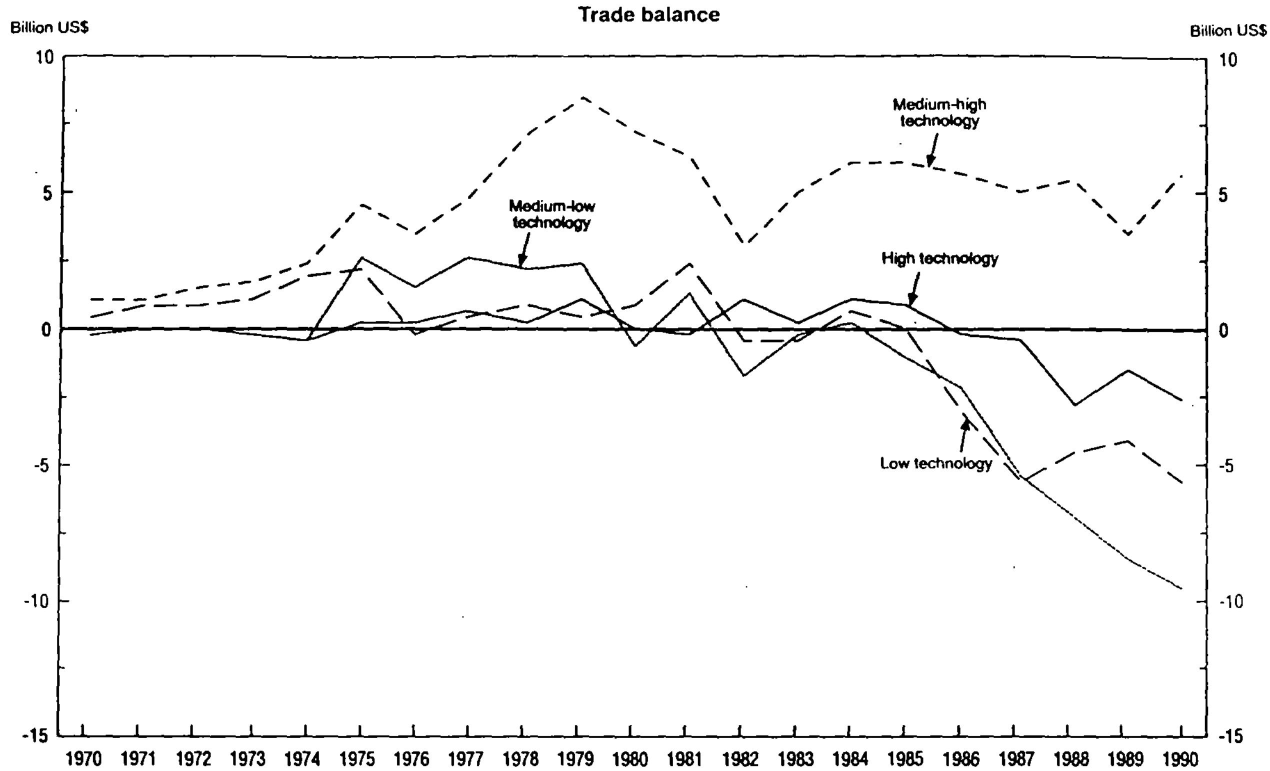
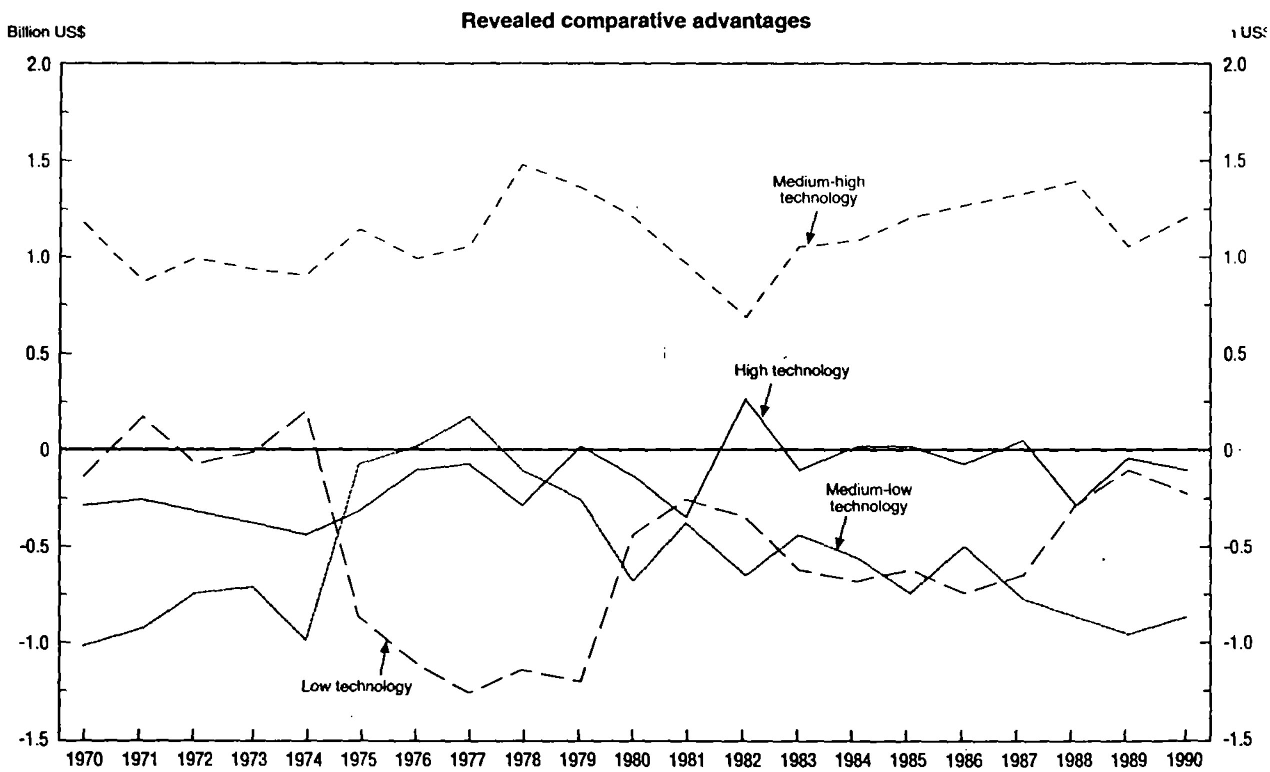
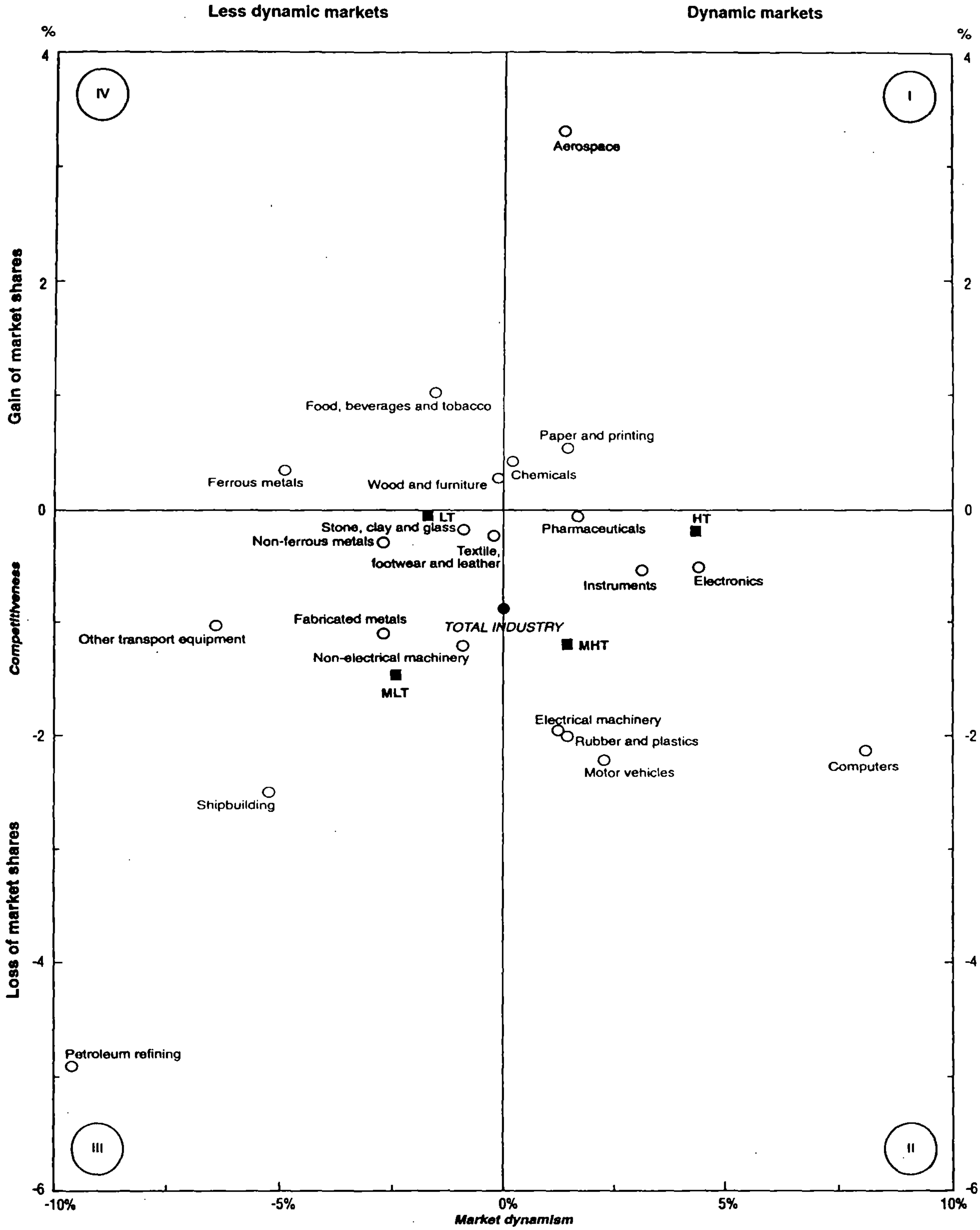
Figure II.32. **France: trade balance and revealed comparative advantages**





Source: OCDE, AES Division, STAN database.

Figure II.33. **France: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

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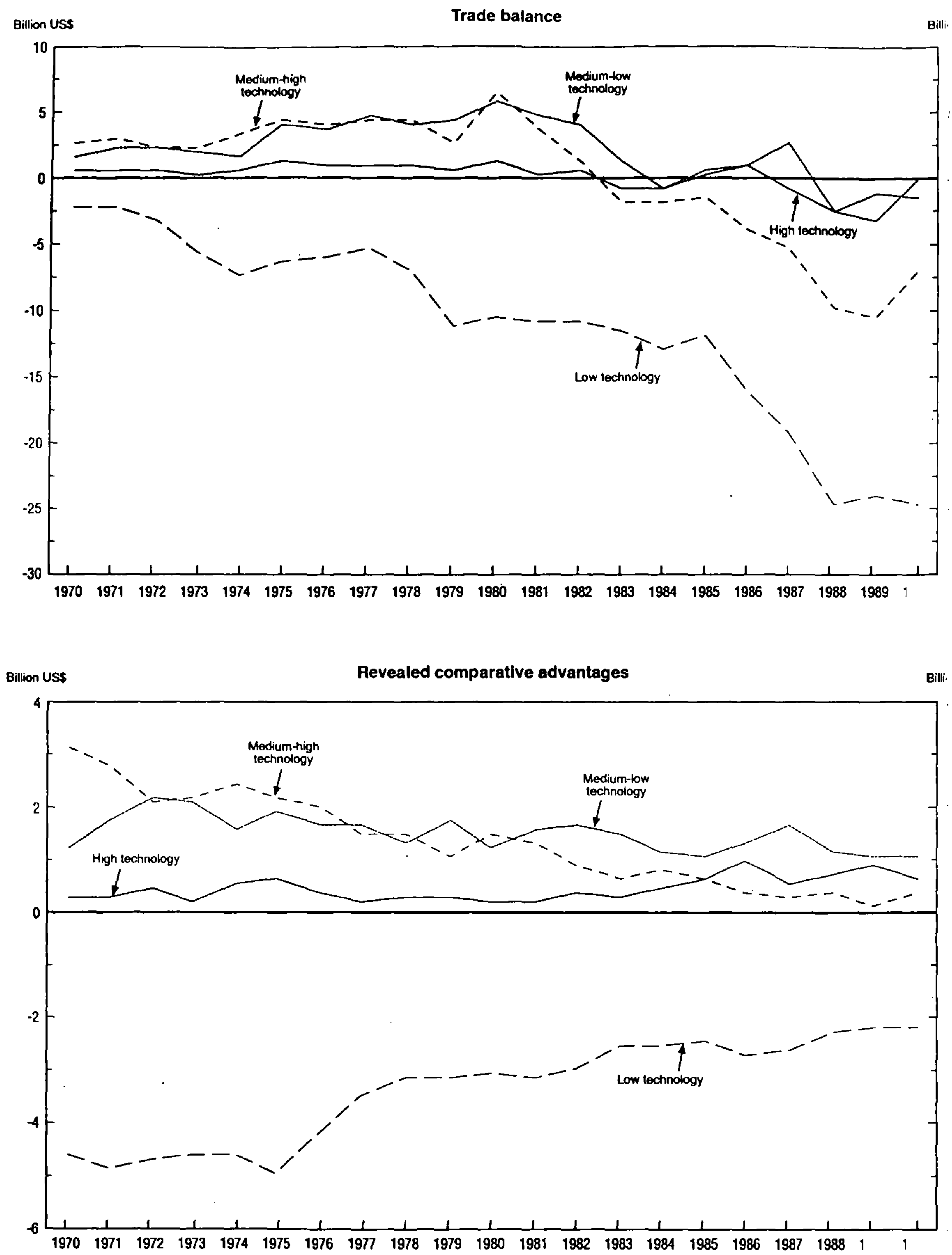
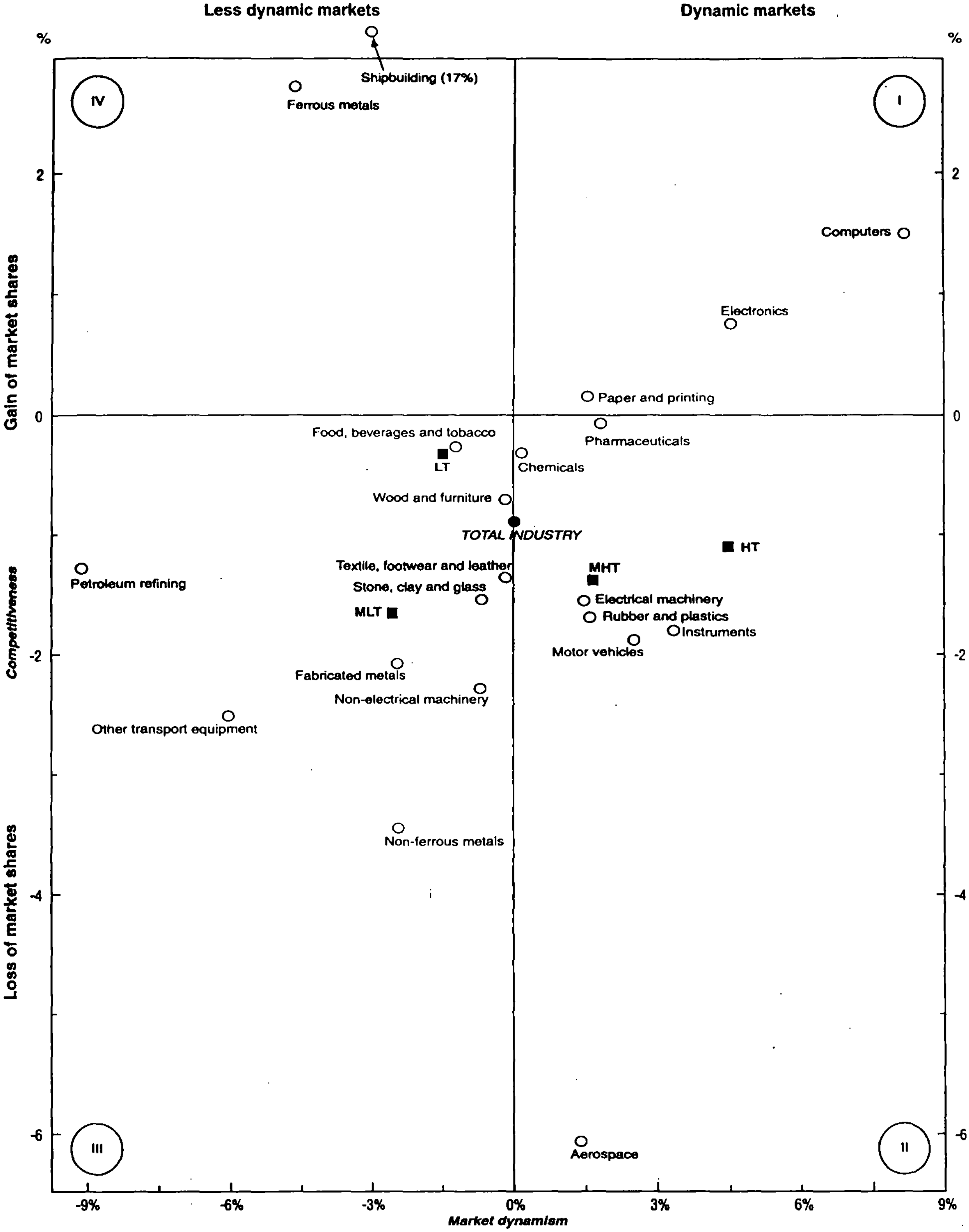
Figure II.34. **United Kingdom: trade balance and revealed comparative advantages**



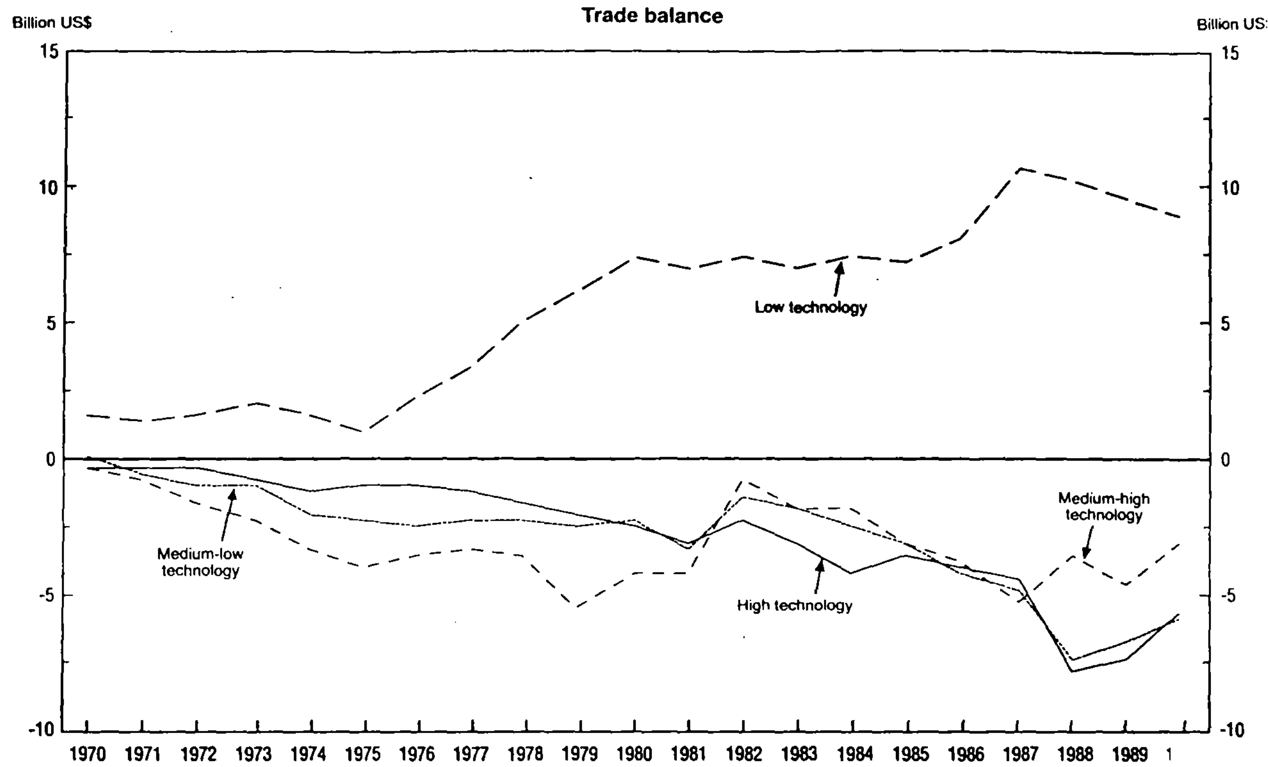
Source: OCDE, AES Division, STAN database.

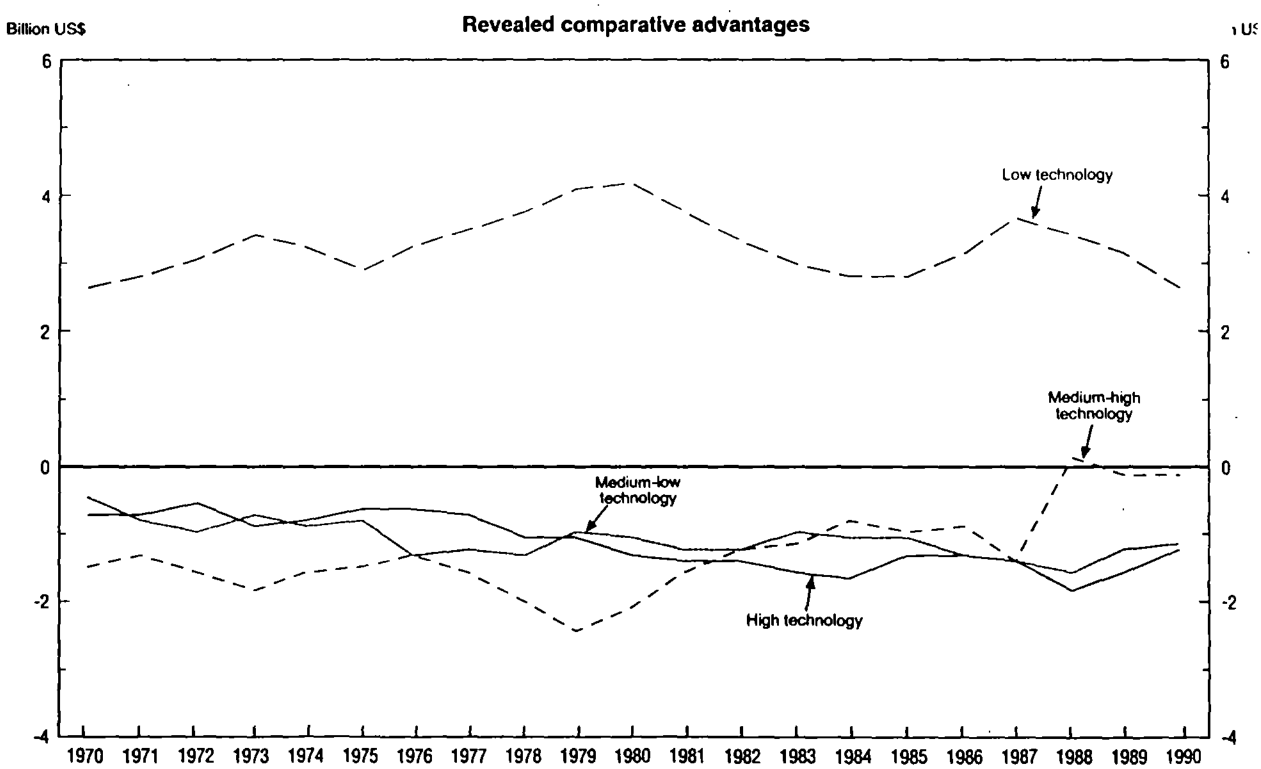
Figure II.35. **United Kingdom: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

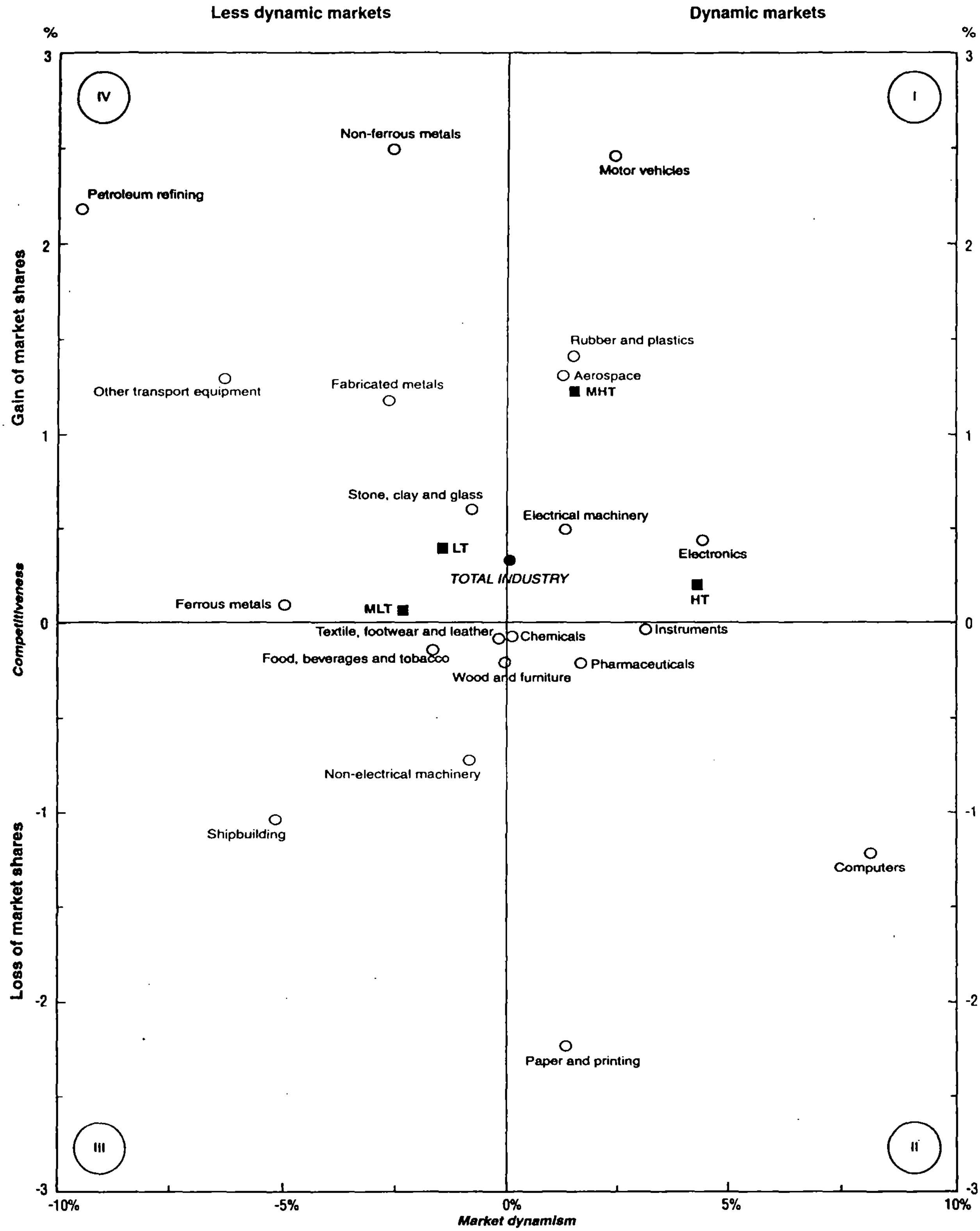
Figure II.36. **Canada: trade balance and revealed comparative advantages**





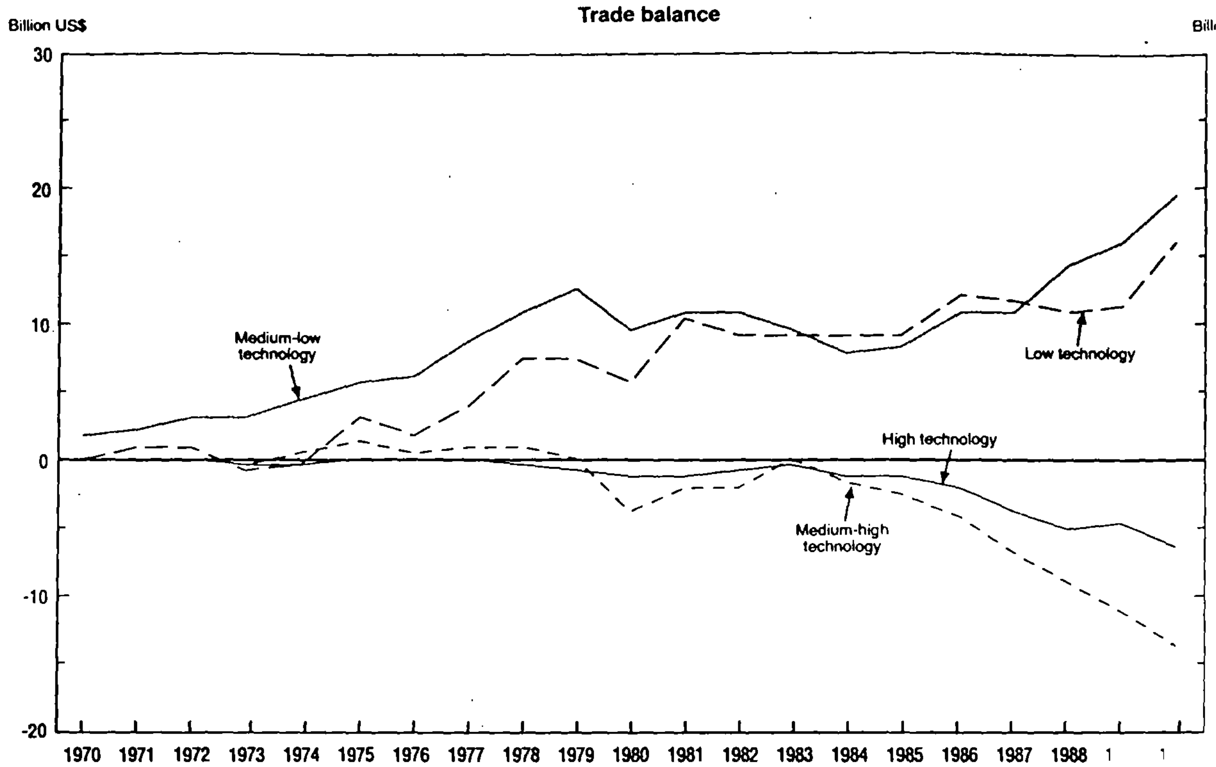
Source: OCDE, AES Division, STAN database.

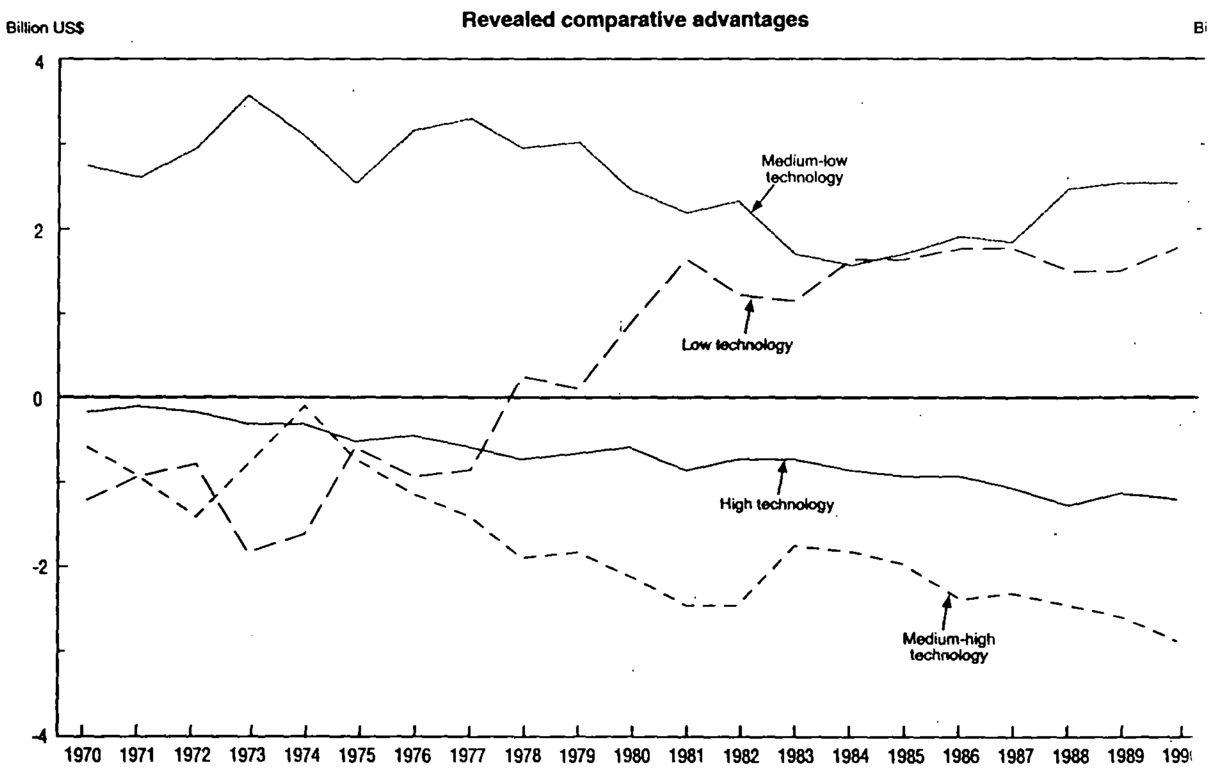
Figure II.37. **Canada: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

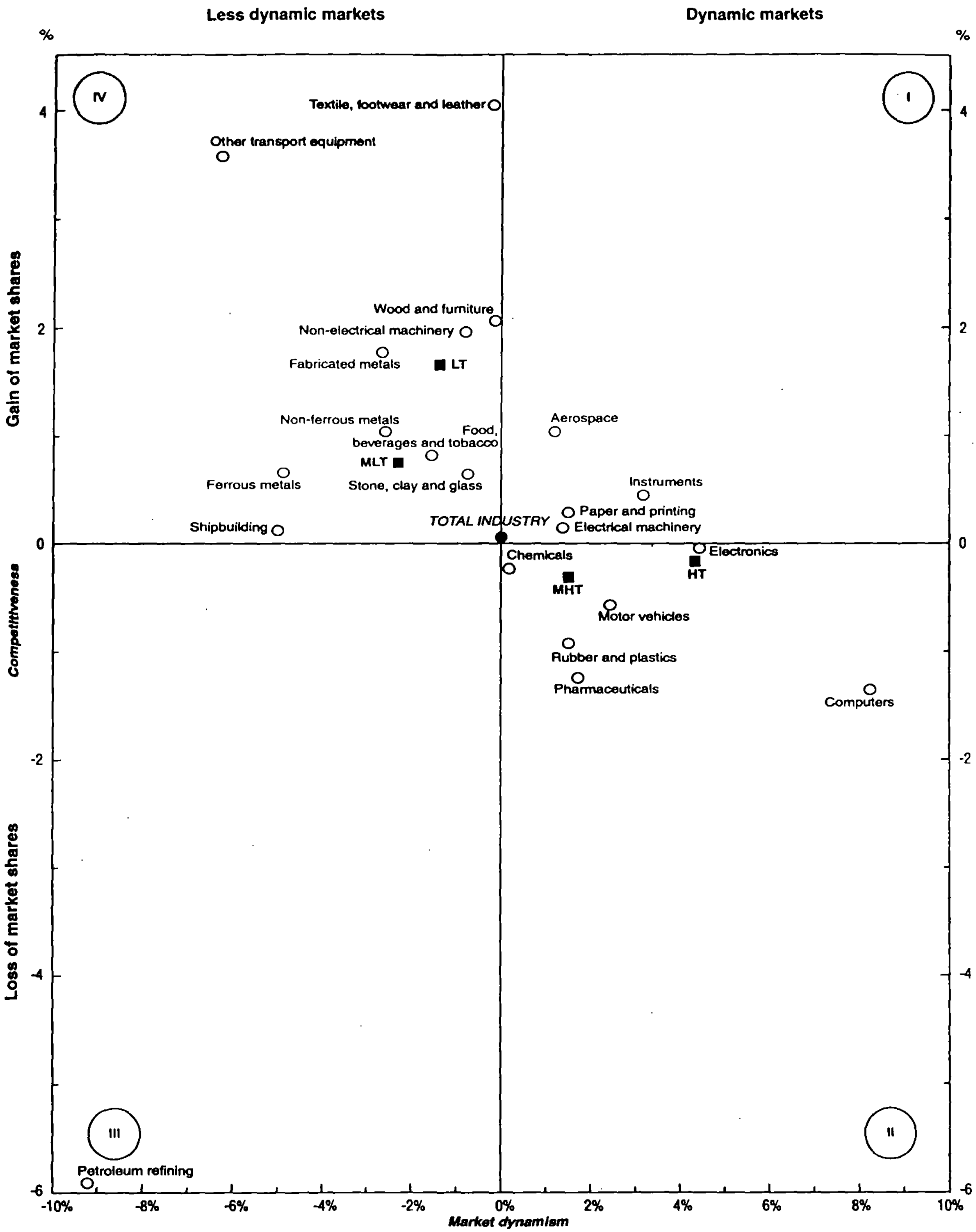
Figure II.38. **Italy: trade balance and revealed comparative advantages**





Source: OCDE, AES Division, STAN database.

Figure II.39. **Italy: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

of its markets but lost some of them again in the second half of the 1980s. The 1990 market shares were slightly higher than in 1980 but considerably lower than in 1985. Secondly, imports increased rapidly, particularly in the sectors with the higher gains in foreign shares, *i.e.* the high technology sectors. Accordingly there was no marked improvement in the trade balance.

Canada's competitive industrial sectors are non-ferrous metals, the wood, paper, refinery and oil industries, and, to some extent, the chemical industry. The two main reasons for this specialisation are the abundance of natural resources and the proximity of the US market, which accounts for over 50 per cent of Canada's exports. As a result of these two factors, Canadian industry has adopted a specialisation structure complementary to that of the United States; this is the case, too, in certain high technology sectors (aerospace and telecommunications).

2.4 Specialisation in medium technology industries

The Netherlands and Sweden, which are comparable in size, have maintained an exceptionally strong R&D effort. Their trade balances are positive in the medium-high, medium-low and low R&D-intensity industries and negative or partly so (Sweden) in the high R&D-intensity industries (see Figures II.40 and II.42). Their competitiveness has declined in overall terms on external markets and the only gains in export market shares have been in the low technology sectors (see Figures II.41 and II.43).

After benefiting from higher oil prices in the 1970s, the Netherlands exporters lost a little ground in the 1980s, mainly because two major industries – electronics and oil refining – had become less competitive. As Figure II.42 shows, other sectors improved their market shares (computers and office machines). Thus, the high and medium-high technology sector accounted for 35 per cent of manufacturing exports at the end of 1970 but for over 42 per cent on average during 1980-90. This result was due to the improved competitiveness of the strong-growth sectors. In 1970, these accounted for 27 per cent of exports and by the end of the 1980s, for slightly over 40 per cent.

Sweden's industry recorded slight but persistent losses throughout the period 1970-90. Hardest hit were two traditional sectors (paper and wood/furniture) and two others among the most technologically dynamic: computers and electronics (see Figure II.43). The structural adjustments of the 1980s seem to have produced quite satisfactory results, since the export shares of certain high-growth industries (aerospace, pharmaceuticals, scientific instruments, chemicals) doubled from 6.5 to 11.7 per cent, though that of various low-growth sectors (wood, textiles, non-metallic ores, steel, shipbuilding) decreased from 20.5 to 11.9 per cent.

3. Pattern of trade flows between the United States, the EC and Japan

The economic relations between the main industr ised countries are now developing in a world-wide c text of globalisation and regionalisation. In the 20 years, trade in manufactured products, and part larly in high technology goods, has been concentrate the Triad (Europe, Japan, the United States) and As newly industrialising economies.[6] At the end of 1980s, 76.5 per cent of Japan's manufactured exports 67.6 per cent of the EC's were going to the Triad ec mies, compared with 63.4 and 59.5 per cent, respecti in the early 1970s.

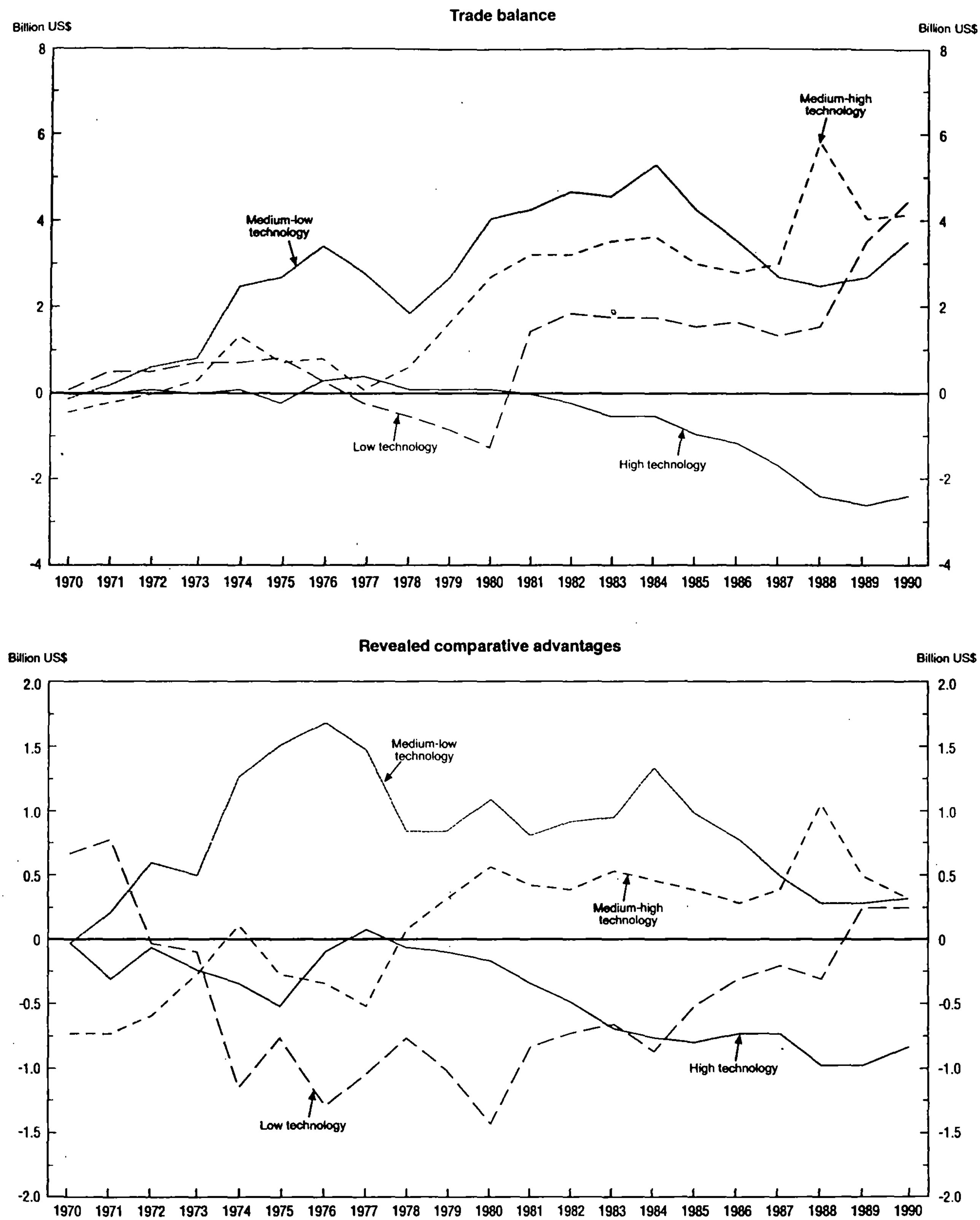
An analysis of the contributions to bilateral bala among these three regions shows that the United S has a comparative advantage over Japan in the low t nology industries and over the EC in the high techno sector. Japan has a comparative advantage over United States in the medium-high and over the EC i high technology sector. Lastly, the EC has a compar advantage over Japan in low technology and over United States in medium-low technology Figure II.44).

An analysis of the Triad's bilateral trade bal also reveals these comparative advantages (see ure II.45). The position of the United States in its bil trade relations with Japan has deteriorated since the of the 1970s; the decline was particularly marked i first half of the 1980s. The United States' trade d with Japan has widened mainly in the medium-high nology industries and to a lesser extent in the hig medium-low sectors. However, from the second h the 1980s, the United States earned surpluses in with Japan in the low technology sector.

Bilateral trade in manufactured products be the United States and the EC is, on the whole, sensitive to the economic climate and to the rise a of the dollar against European currencies, as sho alternating surpluses and deficits at least up t 1982-83 recession. From that date until 1986, wh dollar rose sharply, the US trade deficit with t again increased, but with the fall in the US d shrank considerably, from $30 billion in 1986 to lion in 1990. The deficit was attributable mainly t in low technology products, though the medium-hi medium-low technology sectors also contributed. other hand, the United States' high technology p trade balance with the EC has always remained p Even in the period when its price competitivene greatly deteriorated, the United States maintai surpluses.

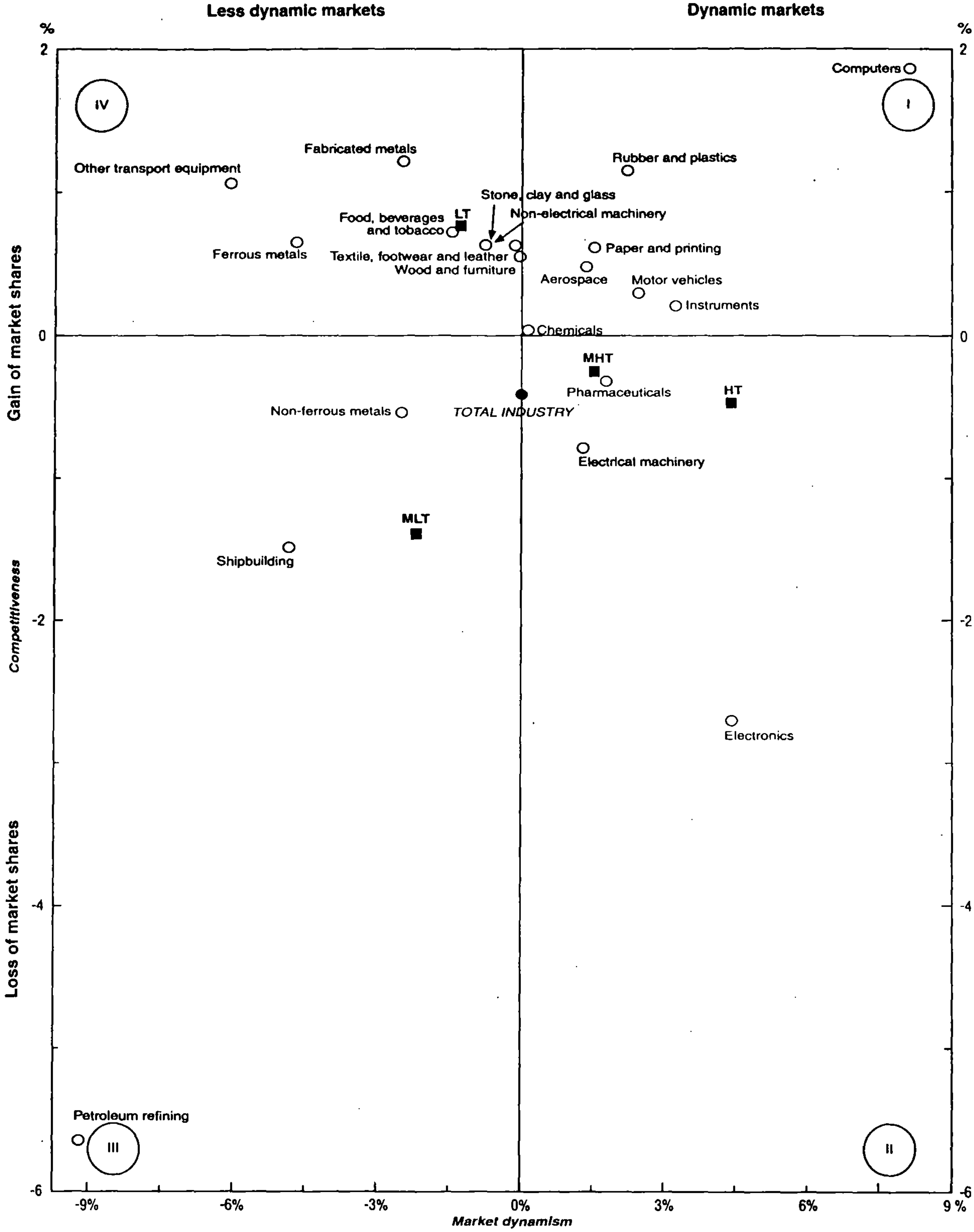
Japan recorded substantial surpluses in its m tures trade with the EC throughout the period. Th EC deficit is attributable mainly to the high and m high technology sectors. Only the low technolog tries have provided surpluses for the EC in its tra Japan since 1978.

Figure II.40. **Netherlands: trade balance and revealed comparative advantages**



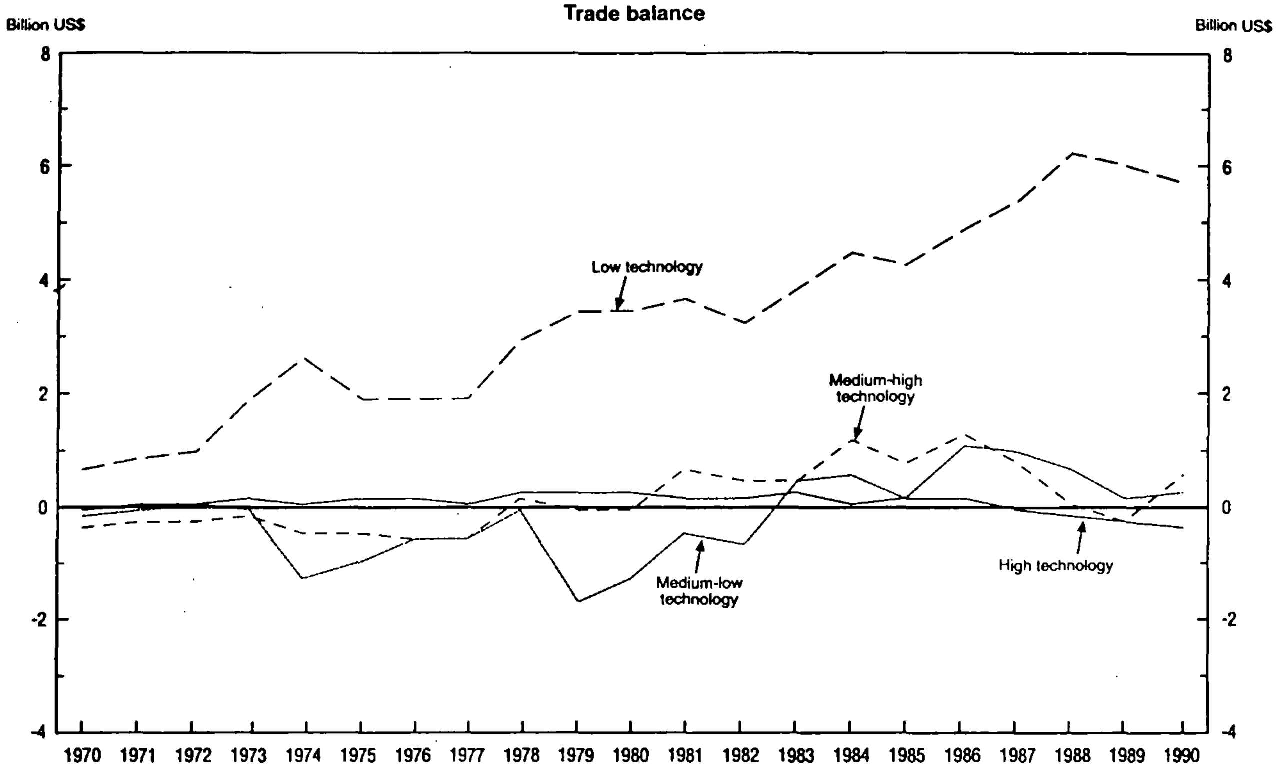
Source: OCDE, AES Division, STAN database.

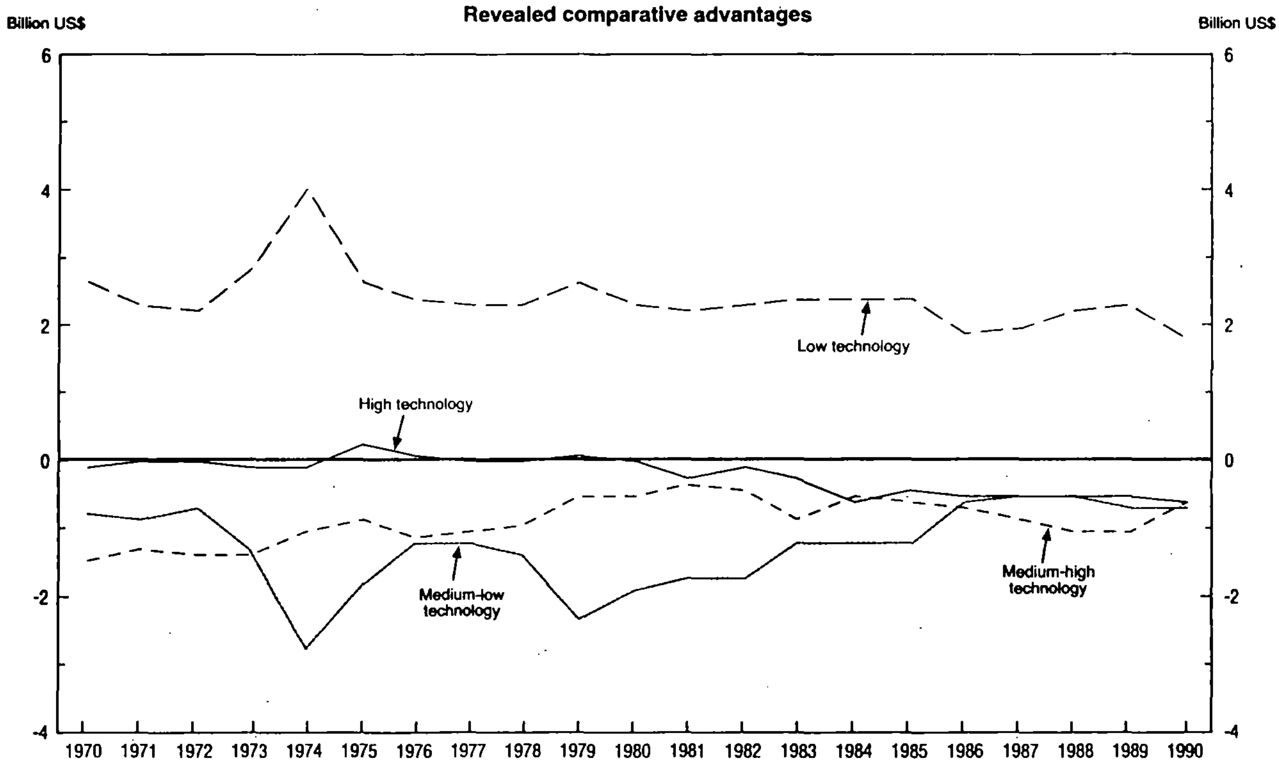
Figure II.41. **Netherlands: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

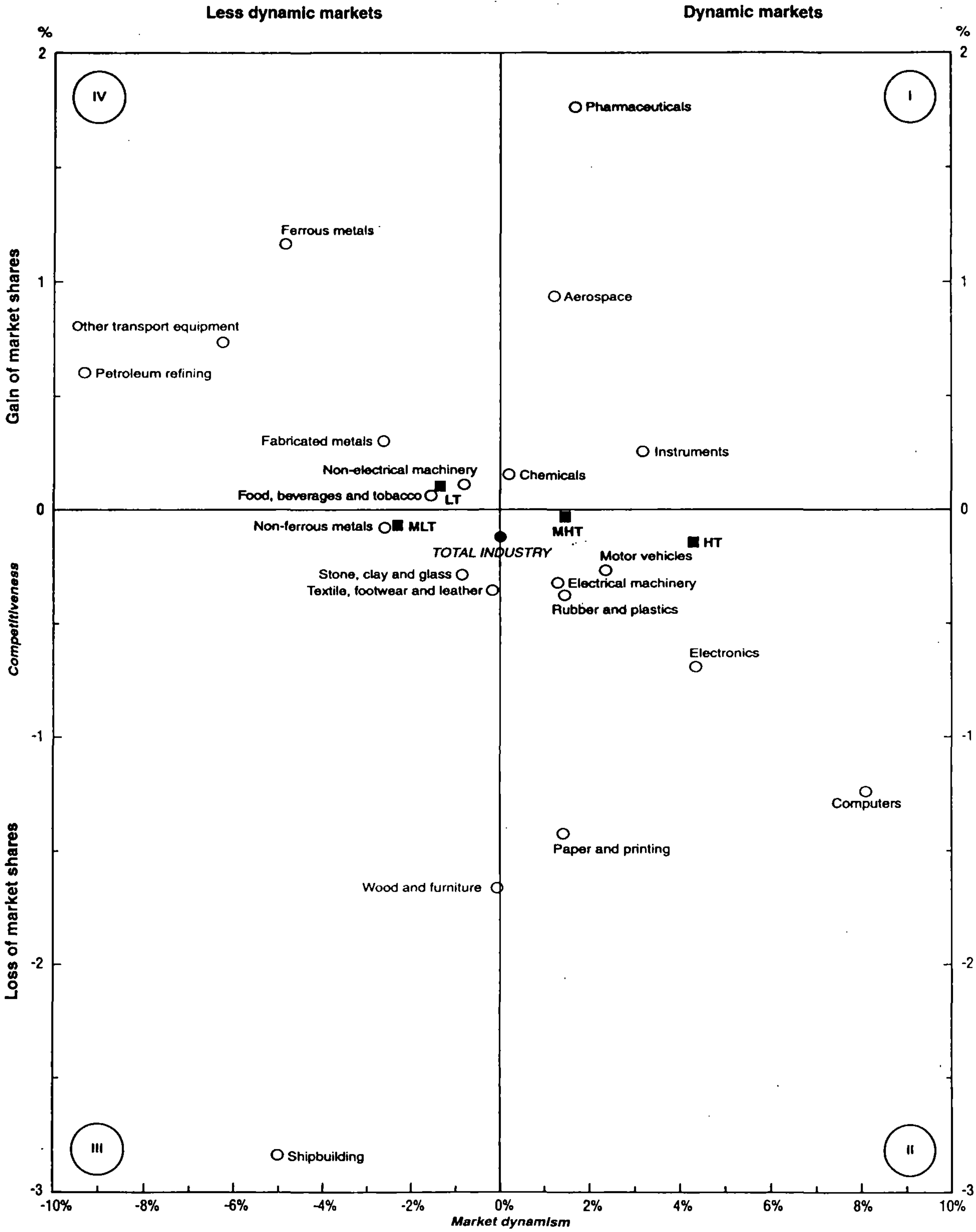
Figure II.42. **Sweden: trade balance and revealed comparative advantages**





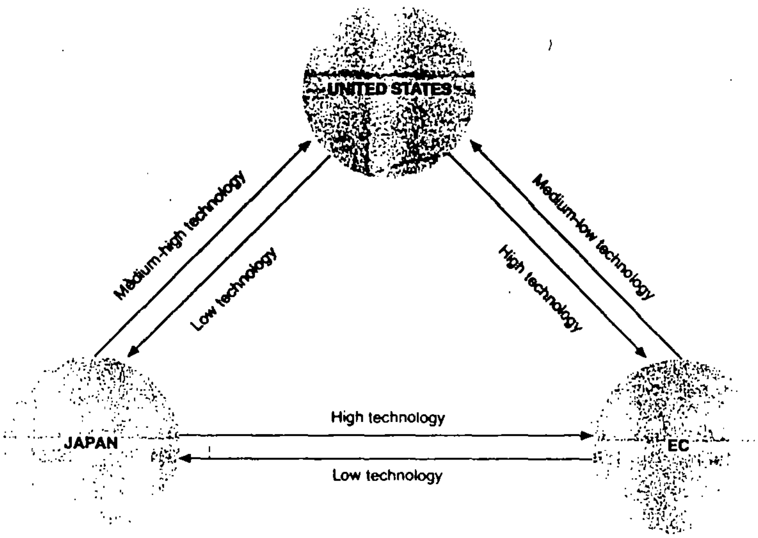
Source: OCDE, AES Division, STAN database.

Figure II.43. **Sweden: positioning and competitiveness**
(1980-90)



Source: OCDE, AES Division, STAN database.

Figure II.44. **The Triad: bilateral specialisation**



Source: OECD Secretariat.

4. Comparative advantages and technology intensities

This section takes the preceding analysis further by comparing the comparative advantages (contributions to the balance) and the R&D intensities specific to each country in each of the four industry groups (high, medium-high, medium-low and low technology).

On the comparative advantage side, average value was calculated over the reference period 1988-90, while R&D intensities were postdated by an average of five years (average for the period 1983-85) to allow for the time lag between R&D effort and initial commercial results.[7]

4.1 High technology

Figure II.39 confirms the findings set out above. Only three countries have a distinct comparative advantage in the high technology group: Japan, the United States and, to a lesser extent, the United Kingdom. But it is their level of R&D intensity which differentiates these countries. In the United Kingdom and the United States, high technology is, to a large extent, related to defence R&D, while in Japan it is almost exclusively concerned with civil R&D and consumer markets.

Unfortunately, the level of aggregation for high technology is such that a sectoral approach does not make it possible to distinguish between the markets involved, *i.e.* mainly procurement contracts or mainly consumer markets, although a product approach would make it possible to do so.

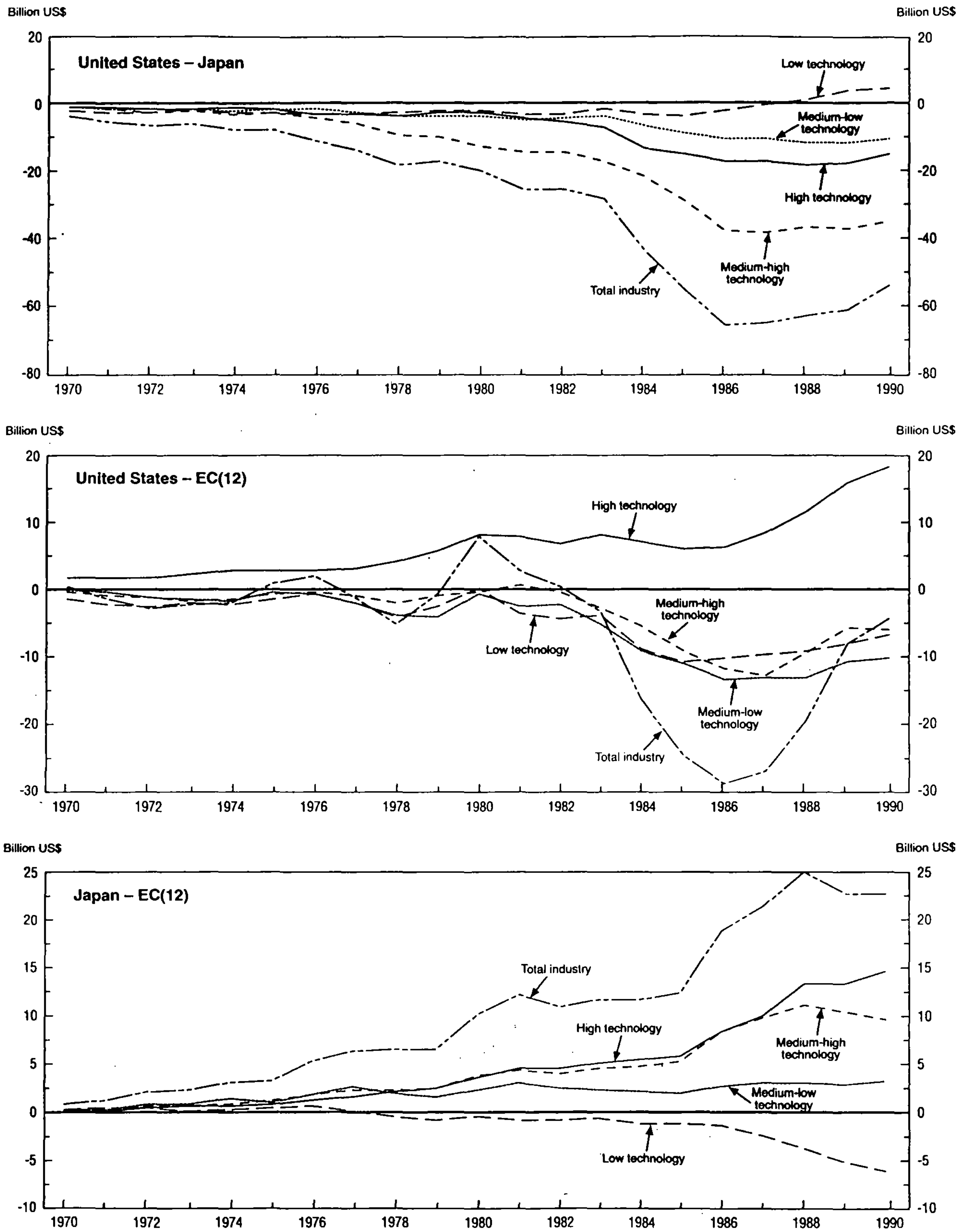
Canada,[8] France, and to a lesser extent, Germany, have quite high R&D intensities as compared with their comparative advantages. France's case would be partly explained by the share of defence R&D for which commercial outlets remain limited, whereas other factors might play a greater role for Canada and Germany.

4.2 Medium-high technology

As indicated above, Germany and Japan have the greatest comparative advantage in this industry group. France is in an intermediate position in terms of both R&D intensity and comparative advantage. The United States again differs from the other countries owing to the relatively high R&D intensity in this group of industries, whose contribution to the balance is close to zero. This situation is probably mainly ascribable to the automobile industry, which accounts for over a third of the United States trade deficit, although its R&D intensity exceeds the Japanese sector's by 60 per cent and the German sector's by 40 per cent.

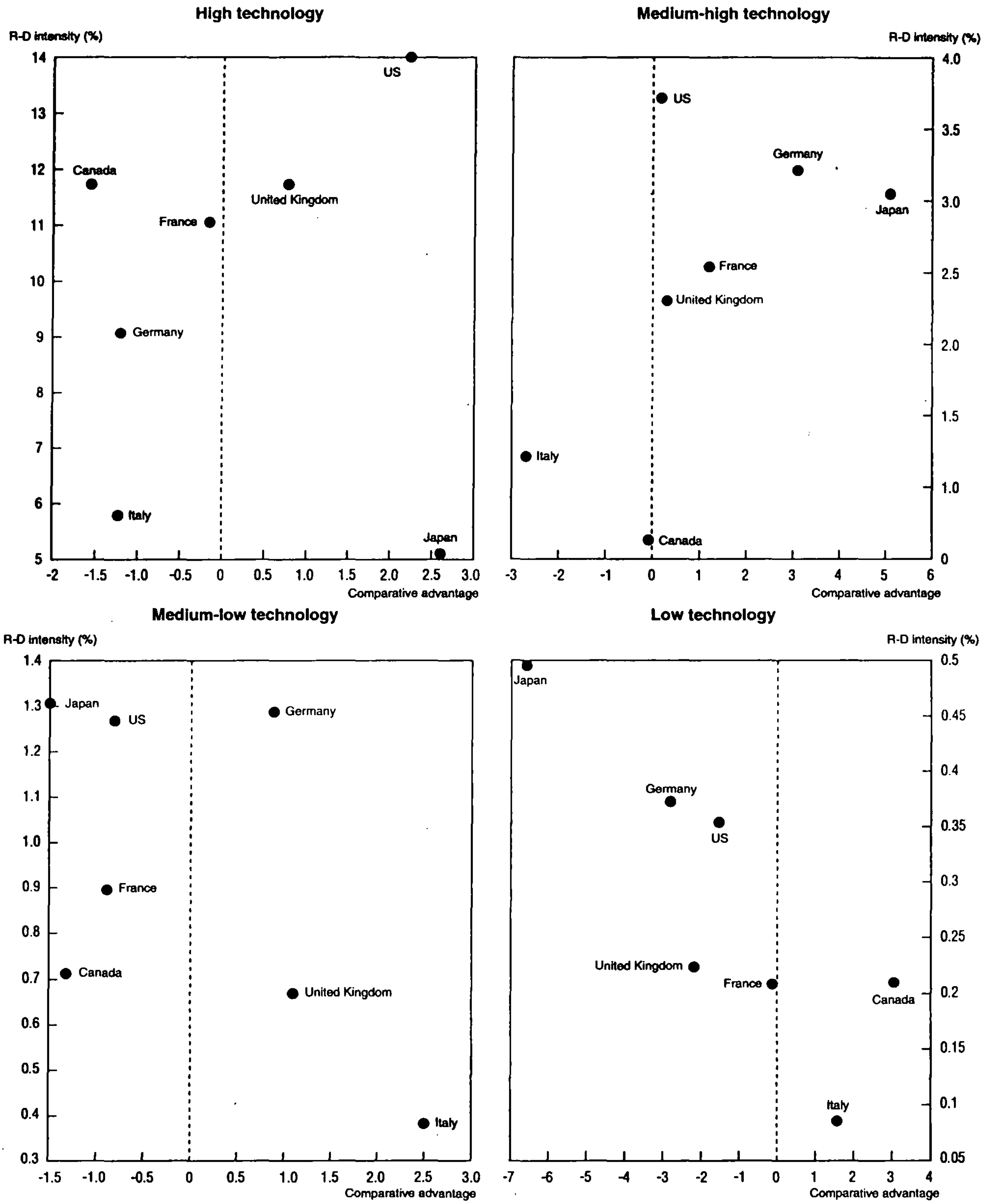
In the absence of other major explanatory factors such as the existence of defence R&D, these differences in automobile industry R&D intensities could be explained only by a more detailed analysis of the

Figure II.45. **Balance of bilateral trade in manufactured products**



Source: OECD, EAS Division, calculations based on STAN data.

Figure II.46. **Comparative advantages[1] and R-D intensities[2]**



1. Contribution to balance (average 1988-90).
2. R-D/Production (average 1983-85).
Sources : OECD Secretariat.

industry's competitiveness. In this area, factors other than technology (*e.g.* organisation, management) are decisive.

4.3 Medium-low technology

Of the seven leading countries, only three have significant trade surpluses in the medium-low technology sectors: Germany, Italy and the United Kingdom.

The case of Italy is peculiar in that this industry group contributes substantially to the trade surpluses despite a very low R&D intensity compared with that of its partner countries. In Japan and the United States, the relatively high intensities could be explained by a wish to keep an adequate technological base and prevent an undue increase in the trade deficit.

4.4 Low technology

Figure II.46 again shows Canada's and Italy's high degree of specialisation in low technology, despite their low R&D intensity in this sector. It also shows the pattern of R&D intensity in Japan where, compared with other countries, it is lowest in high technology and highest in low technology. This suggests that R&D in Japan is less concentrated in a small number of sectors and more evenly distributed over the entire industrial fabric.

5. Conclusions

The above results show that there is no direct and systematic link between the R&D-intensity level of an industry and its trade performance, particularly its capacity to create surpluses. Thus, in high technology, Japan, for example, generates as much surplus as the United States, but with an R&D intensity that is three times less. In the automobile industry this phenomenon is amplified, in that the US automobile industry, with twice the R&D intensity of Japan's, has a large trade deficit with the latter country.

Although research and development are a key factor in industrial competitiveness, it depends on many other factors which are at least as important. If the absolute or relative level of certain investments is undoubtedly very important, the interaction of these investments is just as much so. There has as yet been little work done on the interaction between different categories of tangible and intangible investment and their impact on competitiveness. This is undoubtably a key area for further research.

A strong but narrow specialisation limited to a few industries will only contribute to a balanced trade balance, if the industries concerned play an important role in the countries trade and *a fortiori* if they are assisting the growth sectors in world trade. In countries in which the trade balance of manufactured products is positive, certain industries seem to play this growth role, *e.g.* electronics and automobiles in Japan, chemicals and automobiles in Germany, textiles, footwear and clothing and non-electrical machinery in Italy.

If the specialisations of countries are considered in bilateral terms, it appears that:

- The United States, whose strengths lie in high technology, only shows trade surpluses in these industries with the EC, whereas with Japan, trade surpluses are only registered in low technology sectors.
- The EC, which shows a trade deficit in high technology both with the United States and with Japan, only generates surpluses in the medium-high technology sectors with the United States and in the low technology sectors with Japan.
- Japan, in turn, has trade deficits with both the United States and the EC only in low technology industries. Its commercial advantages with respect to the United States are in medium-high technology sectors and with the EC in the high technology sectors.

The EC's dependence in high technology is largely attributable to the electronics industry and to computers. As underscored above, these two industries register the greatest growth in world trade and account for two-thirds of trade in high technology products. Consequently, it would be difficult to envisage an improvement of the trade balance in high technology without a significant reduction of the deficit in the electronics and computer industries.

2

NOTES

1. Since the available data do not allow for calculating world trade growth by sector, an initial estimate has been made by evaluating world imports in the light of the exports of 16 OECD countries to the non-OECD area.

2. The revealed comparative advantage (RCA) for a country i and a sector j is defined as:

$$RCA_{ij} = 100. \frac{X_{ij} / \sum_{j} X_{ij}}{\sum_{i} X_{ij} / \sum_{i}\sum_{j} X_{ij}}$$

where X_{ij} denotes the exports of country i in sector j.

3. The performance by Japanese industry in high technology sectors could also be explained by a higher technical progress input (total factor productivity) than in other major countries. In other words, Japan's productive system has a very great capacity for assimilating technological innovation within these sectors.

4. In terms of comparative advantages contributing to the balance.

5. With the exception of the automobile industry, these sectors gained market shares between 1980 and 1990.

6. South Korea, Hong Kong, Singapore, Taiwan, Thailand, Indonesia, Malaysia and the Philippines.

7. The average lag of five years for R&D is in fact a somewhat arbitrary choice. It is considered that in some sectors it should be more and in others less than five years. Strictly speaking, it would be necessary to assess the time lag for each individual industry in each country and then take the average for each industry group. This operation, which is essential particularly for the calculation of R&D capital stock in the various sectors has not been carried out systematically. However, preliminary econometric studies have shown that differences in time lags have comparatively little effect on the results.

8. It should be pointed out here that the dispersion of R&D intensity between the high-technology group and the other industry groups is greater in Canada than in any other country.