

World 2004 ROBOTICS

Statistics, Market Analysis,
Forecasts, Case Studies and
Profitability of Robot Investment



Co-authored by:
**THE INTERNATIONAL
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FOREWORD

Since their introduction at the end of the 1960s, industrial robots have undergone an impressive technological evolution. With declining real prices and continuously improved performance, robots are now widespread in industry in many countries while in others the technology is on the verge of being introduced.

Robots have become a symbol and a test of industrial automation in its most advanced form. Together with computerized numerically controlled machine tools, automated guided vehicles and host computers of various kinds, robots form the centrepiece of computer-integrated manufacturing systems.

The introduction of industrial robots is not only motivated by a wish to improve productivity but also to obtain higher and more consistent product quality. Robotics is also an important technology for eliminating workplace hazards, e.g. those related to exposure to heat, gases and chemicals or those where heavy lifting or monotonous work movements are involved.

Total accumulated yearly sales of robots since the beginning of the 1970s amounted at the end of 2003 to some 1.4 million units, of which some 800,000 are estimated still to be in operational use. Driven by advances in semiconductor and computer technologies and the vast potential for new applications, not only in industry but also in construction and in services (hotels, health care, laboratories, surgery etc), there is every reason to believe that robotics will continue to expand rapidly and play an increasingly important role in production rationalization.

This yearly publication, in addition to summarizing the development of industrial robots to date, presents time-series data for the period up to 2003 and inclusive, forecasts for the period 2004-2007 and, for the fourth year in a row, an analysis of the diffusion of service robots. It is a joint effort of the United Nations Economic Commission for Europe (UNECE) and the International Federation of Robotics (IFR). The two organizations have enjoyed close and fruitful co-operation in the area of robotics for many years.

Monitoring economic and social trends, developing indicators with a focus on performance and outcomes, supporting business and policy decisions with an infrastructure of good quality information and analysis, are core preoccupations and strategic objectives of the UNECE Statistical Division. This Report therefore provides an outstanding illustration of what can be achieved in monitoring industrial development.

The present publication and all previous yearbooks on robotics were written by Mr. Jan Karlsson, Chief Economic Statistics Methodology Section, ECE Statistical Division with the assistance of the IFR secretariat. Mr. Yves Clopt, ECE, designed the cover page and made the photo set-ups. Ms. Linette Blanchandin, ECE Statistical Division, assisted in the text processing and the proof reading of the publication.

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EXECUTIVE SUMMARY

WORLDWIDE DIFFUSION OF INDUSTRIAL ROBOTS

2003 World Robot Market

Total world-wide sales: 81,800 units, +19% over 2002

**World stock of operational industrial robots:
800,000 units, +4% over 2002**

World market surged by 19% in 2003...

Worldwide sales of multipurpose industrial robots peaked in 1990 when they reached over 80,000 units. Following the recession in 1991-1993, worldwide sales of industrial robots fell to about 53,000 units in 1993. The world robot market then started a period of strong recovery, which peaked in 1997 when it reached a level of 82,000 units. In 1998, however, sales plunged by 16% to just under 69,000 units. The market recovered sharply in 1999 with sales of nearly 80,000 units, an increase of almost 15% over 1998. In 2000, growth accelerated to 24%, attaining a record of almost 99,000 units. In 2001 and 2002, however, the world market fell by 21% and 12%, respectively, reaching 68,600 units. **A strong recovery was recorded in 2003. The world market grew by 19% to 81,800 units.**

...as a result of increased demand in all major markets: Japan +25% and North America +28%

After two years of falling or stagnant sales, there was a sharp recovery in Japan in 2000. Sales of all types of industrial robots surged by 32% over 1999, reaching almost 47,000 units. As from 2001, data for Japan exclude almost all dedicated robots (only dedicated robots for machining are included). Data for 2000 and 2001 are thus not comparable. Between 2001 and 2002, however, sales in Japan fell by almost 11% to about 25,400 units. **A buoyant recovery started in 2003 when the market grew by almost 25% to 31,600 units.**

From 1995 to 2000, the robot market in the United States was booming every second year and, in the years between, it was flat or falling. In 1995, 1997 and 1999 it increased by 32%, 28% and 37%, respectively. By contrast, in 1996 and 1998, the market dropped by 5% and 13%, respectively, while in 2000 it was almost flat (+1%). However, the highest sale of multipurpose industrial robots, in their strict definition, ever recorded was in 2000 when it reached nearly 13,000 units. In 2001, the market fell by nearly 17% to 10,800 units followed by another drop of 8% in 2002 to just under 10,000 units. **In 2003, however, there was a sharp recovery. The market expanded by 28% to about 12,700 units.**

The market in the European Union rose by 4% ...

In the European Union, sales of multipurpose industrial robots rose by 18% in 2000 to 29,800 units. In 2001, sales continued to grow but by a modest 3%, reaching 30,800 units. With the exception of 1997, when the market fell by 1%, the European Union has had market growth since 1994 and, except for 2001, double digit growth. This came to a halt in 2002, when the market fell by 15% to 26,100 units. **In 2003, there was a slight recovery of 4% to 27,100 units. There were, however, large variations between countries – from an increase of 48% in the United Kingdom to a decrease of 46% in Austria.**

Europe and the United States are rapidly catching up with Japan...

In the early 1990s, **installations of multipurpose industrial robots** in the European Union and the United States only amounted to about 20% and 7%, respectively, of Japan's installations of (all types of) industrial robots. Following the more restrictive reporting by Japan, data show that in 2001-2002 **more multipurpose industrial robots were installed in the European Union than in Japan**. In 2003, however, the market in Japan was again larger than that of the European Union.

Looking at the **operational stock** of industrial robots, again relating Japan's stock (to which all types of robots were added up to and including 2000) to those of multipurpose robots in the European Union and the United States, the same pattern prevails. **The EU stock rose from 23% of that of Japan in 1990 to almost 72% in 2003. The corresponding figures for the United States were 12% and 32%, respectively.** Again, if separate data had been available for multipurpose industrial robots in Japan, they might very well have shown a stock of a magnitude between that of the United States and that of the European Union.

Robots do much better than most other investment goods...

While in 2002 the value of market for industrial robots fell by 8% in the United States, the market for machine tools fell by as much as 36%. In Japan and Germany the same pattern was prevailing. Machine tools fell by 32% and 20%, respectively, while robots "only" fell by 11% and 7%.

In 2003, growth in robot investment again largely surpassed machine-tool investment.

Estimate of the worldwide operational stock of industrial robots

Total accumulated yearly sales, measured since industrial robots started to be introduced in industry at the end of the 1960s, amounted at the **end of 2003** to some **1,410,000 units, including, as mentioned before, the dedicated industrial robots installed in Japan up to and including 2000**. Many of the early robots, however, have by now been taken out of service. The stock of industrial robots in actual operation is therefore lower. Based on the assumptions made in chapter I, UNECE and IFR estimate the

**total worldwide stock of operational industrial robots
at the end of 2003 between a minimum of 800,000 units
and a possible maximum of 1,090,000 units**

The minimum figure above is, as was discussed in chapter I, derived on the assumption that the average length of **service life is 12 years**. A UNECE/IFR pilot study has indicated that the average service life might in fact be as long as **15 years**, which would result in a **worldwide stock of 1,090,000 units**.

The minimum 2003 stock of just over 800,000 units can be compared with 770,000 units at the end of 2002, representing an increase of 4%. As can be seen from table 1 and figure 2, **Japan accounts for just under half the world robot stock - largely because the Japanese figures include all types of robots**. Its share is, however, rapidly diminishing.

Forecasts for 2004-2007

The world market for industrial robots is projected to increase from 81,800 units in 2003 to 106,000 in 2007 or by a yearly average of 6.8% (see table 1 and figure 1).

Sales in Japan expected to show continued strong recovery...

Growth in robot investment in Japan will be spurred by an increasing demand for replacement investment. Between **2003 and 2007**, sales are projected to increase **from 31,600 units to some 41,000 units**.

Table 1

Installations and operational stock of multipurpose industrial robots in 2002 and 2003 and forecasts for 2004-2007. Number of units

Country	Yearly installations				Operational stock at year-end			
	2002	2003	2004	2007	2002	2003	2004	2007
Japan	25,373	31,588	33,200	41,300	350,169	348,734	352,200	349,400
United States	9,955	12,693	12,800	15,900	103,515	112,390	121,300	145,100
European Union	26,096	27,114	28,800	34,400	233,769	249,200	266,100	325,900
Germany	11,862	13,381	14,100	16,300	105,212	112,693	121,500	151,400
Italy	5,470	5,198	5,500	6,400	46,881	50,043	53,100	63,400
France	3,012	3,117	3,300	3,900	24,277	26,137	28,400	35,900
United Kingdom	750	1,111	1,200	1,500	13,651	14,015	14,600	16,300
Austria a/	670	365			3,521	3,602		
Benelux a/	654	715			8,708	9,052		
Denmark	249	288			1,853	2,078		
Finland	376	387			3,151	3,407		
Portugal	138	135			1,282	1,367		
Spain	2,420	2,031			18,352	19,847		
Sweden	495	386			6,881	6,959		
Other Europe	582	922	1,000	1,300	11,009	11,409	11,900	14,200
Czech Rep. a/	87	498			1,022	1,445		
Hungary	61	35			211	216		
Norway	80	48			664	684		
Poland	128	60			622	584		
Russian Fed. a/	21	9			5,000	5,000		
Slovakia b/	24	1						
Slovenia b/	25	31						
Switzerland a/	156	240			3,490	3,480		
Asia/Australia	5,123	6,695	7,200	8,900	60,427	65,419	69,900	78,500
Australia	392	533			3,192	3,571		
Rep. of Korea (all types of industrial robots)	3,998	4,660			44,265	47,845		
Singapore a/	53	48			5,299	5,273		
Taiwan, Province of China	680	1,454			7,671	8,730		
Other countries a/	1,466	2,764	3,200	4,500	11,216	13,620	16,500	27,200
Subtotal, excl. Japan and Rep. of Korea	39,224	45,528	47,900	58,700	375,671	404,193	485,700	590,900
Total, including Japan and Rep. of Korea	68,595	81,776	86,200	106,300	770,105	800,772	886,200	997,700

Sources: UNECE, IFR and national robot associations.

a/ Estimated by UNECE and IFR for some or for all the years.

b/ In the period 1999-2001, included in the aggregate "Other countries".

Figure 1. Yearly installations of industrial robots, 2002-2003 and forecast for 2004-2007

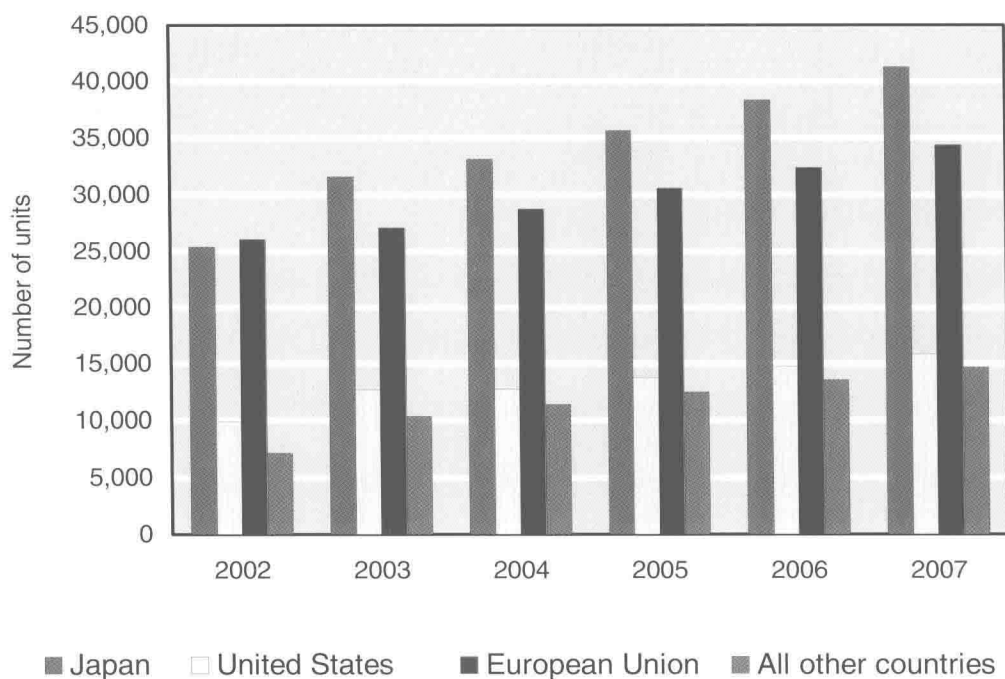
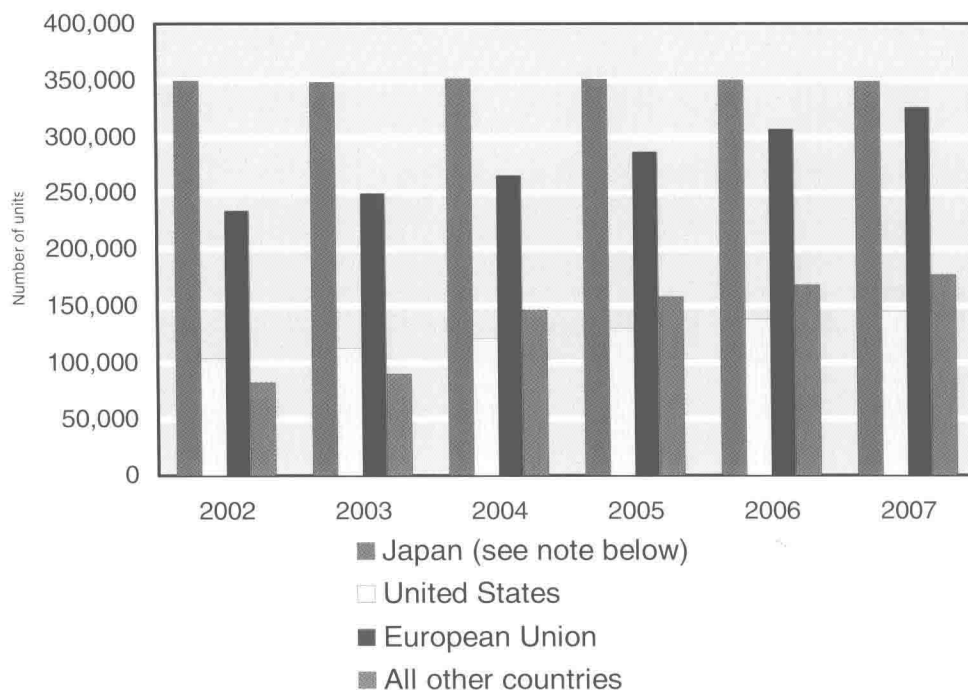


Figure 2. Estimated operational stock of industrial robots 2002-2003 and forecast for 2004-2007



Note 1: Addition to the stock data for Japan included dedicated robots up to and including 2000. Stock data shown here are therefore not fully comparable with those of other countries.

In 2003, just as in the previous five years, more industrial robots were taken out of operation in Japan than new robots installed. The robot stock fell by just over 1,000 units compared with 11,000 units in 2002. In the late 1980s and early 1990s, before the economic slump of 1992/1993, a large number of industrial robots were installed in Japan. The peak occurred in 1990 with over 60,000 robots installed. During the forecasting period, these robots are most likely to be replaced. For this reason, a recovery of the robot market can be expected for the period under review.

Steady growth in Europe and in North America

The robot market in the **European Union** is expected to grow from **27,100 units in 2003 to over 34,000 units in 2007**, representing an annual average growth of 6.1%. In **North America**, the market is estimated to grow by an average annual rate of 5.8%, which implies that the market will reach about 16,000 units in 2007. In view of a somewhat optimistic economic forecast by OECD of a recovery, these forecasts for robotics, mainly based on the opinions of robotics experts, might be somewhat too conservative.

The operational stock of industrial robots continues to grow, except in Japan

In terms of units, it is estimated that the worldwide stock of operational industrial robots will increase **from about 800,000 units at the end of 2003 to 1,000,000 at the end of 2007**, representing an average annual growth of 5.7% (see table 1 and figure 2). It is interesting to note that the operational stock of robots in Japan decreased for the first time in 1998. In 1999-2001, the decrease accelerated. In 2002-2003, however, the rate of decrease slowed down significantly.

The year 1997 was the peak one for the Japanese robot stock, when it reached 413,000 units, including all types of industrial robots. By end 2003, it had fallen to 349,000 units and is projected to remain at that level also in 2007.

In the United States, the operational stock of multipurpose industrial robots is forecast to reach **145,000 units in 2007**. The projection for the **European Union is 326,000 units**, of which 151,000 in Germany, 63,000 in Italy, 36,000 in France and 16,000 in the United Kingdom (see table V.4 and figure V.2).

These estimates of stock data are **minimum figures**. Assuming a longer average service life of robots (15 years instead of 12 years) would significantly increase the estimated stock.

Results in the first half of 2004 – robot sales continue to surge

Looking at the **first half of 2004**, the UNECE/IFR quarterly survey on order intake of industrial robots, which includes most of the world's largest companies, showed that worldwide order intake **increased by 18%**, compared with the same period in 2003. It was the highest order intake of industrial robots ever recorded, worldwide and in all regions, except for Europe where it was the second best half year recorded.

Order intake of industrial robots, first half of 2004 compared with the same period in 2003

North America	+18%	Asia	57%
Europe	-3%	Other regions	0%

Growth in robot investment is spurred by plummeting robot prices but price decreases are starting to level off...

In the 1990s, prices of industrial robots were plummeting while at the same time their performance, measured both for mechanical and electronic characteristics, was improving continuously. A UNECE/IFR survey, which covered the period 1990-2000, showed the following results:

- ◆ List price of one robot unit -43%
- ◆ Number of units delivered +782%

◆ Number of product variants that can be supplied to customers	+400%
◆ Total handling capacity (including gripper module)	+26%
◆ Repetition accuracy	+61%
◆ Speed of the 6 axes	+39%
◆ Maximum reach	+36%
◆ Mean time between failures	+137%
◆ RAM in Mbytes	over 400 times
◆ Bit-size of the processor	+117%
◆ Maximum number of axes that can be controlled	+45%

Prices of industrial robots, expressed in constant 1990 US dollars, have fallen from an index 100 to 59 in the period 1990-2003, without taking into account that robots installed in 2003 had a much higher performance than those installed in 1990 (see figure 3). When taking into account quality changes, it was estimated that the index would have fallen to 25. In other words, an average robot sold in 2003 would have cost only a fourth of what a robot, with the same performance, would have cost in 1990, if it ever had been possible to produce such a robot in that year.

In the same time, the index of labour compensation in, for instance, the American business sector increased from 100 to 156 (see table 2). This implies that the **relative prices of robots in the United States fell from 100 in 1990 to 28 in 2003**, without taking into consideration the enormous improvements in robotics during this period, and to only **12** when taking such improvements into consideration. Other major robot using countries had similar developments in their relative robot prices.

Measurements of robot density based on the total number of persons employed

In figure 4, five groups of countries can be distinguished with respect to robot densities, expressed as the number of robots per 10,000 persons employed in the manufacturing industry (ISIC rev.3: D). The **first group** includes **Japan** and the **Republic of Korea**, whose robot stock includes all types of industrial robots and is therefore not comparable with other countries. In 2003, these two countries had robot densities of about 320 and 140, respectively. While the density in the Republic of Korea is increasing rapidly, it has fallen in Japan since the peak in 1998.

The **second group** is topped by **Germany**, which in 2003 had a density of 148, followed by **Italy** with 116 and **Sweden** with 99 robots per 10,000 employed in the manufacturing industry. The **third group** of countries includes **Finland** with 78, **Spain** with 72, and **France** with 71 robots per 10,000 employed in the manufacturing industry. In the **fourth group**, the densities ranged between 63 and 39 in the **United States**, **Benelux**, **Denmark**, **Austria** and the **United Kingdom**. In **Norway** and **Australia**, the density amounted 24 and 36, respectively, while at the bottom was **Portugal** with 15. Countries in Central and Eastern Europe, with the exception of the Czech Republic, have even significantly lower densities.

Despite this large range in the robot densities of European countries, it is interesting to note that **the robot density in the European Union is about 50% higher than that of the United States**.

Robot densities - 1 robot per 10 workers in the motor vehicle industry

Figure 5 shows data on the number of multipurpose industrial robots per 10,000 production workers in the motor vehicle industry. Japan and Italy are in the lead with 1,400 robots per 10,000 workers but, bearing in mind that Japan includes all types of robots (up to and including 2000), it is not comparable with the densities of other countries. Thereafter follows Germany with a density of 1,000, France 910, Spain 800, United States 740, United Kingdom 660 and Sweden 560. The technological level with respect to robotics is thus rather homogeneous in the motor vehicle industry in most of the above-mentioned countries.

Installations of advanced multipurpose industrial robots with 5 axes or more

When countries collect data, they do not always include the same types of robots - some countries concentrate on the more sophisticated robots while others, e.g. Rep. of Korea, collect data on all types of robots that satisfy the IFR definition. For this reason, country data are not always comparable. Looking only at the subset of **robots with 5 axes or more**, the comparability between countries is significantly improved (see table 3).

Table 2

Price index of industrial robots in the United States, with and without quality adjustment. Index of labour compensation per employee and hourly wages, excluding social costs, in selected industry branches

Year	Index of robot prices, 1990=100		Index of labour compensation		Hourly wages, excluding social costs, production workers, \$		
	without quality adjustment	with quality adjustment	Business sector a/	Manufact. industry (ISIC rev.3:D) b/	Manufact. industry (ISIC rev.3:D) c/	Food industry (ISIC rev.3: 15+16) c/	Motor veh. industry (ISIC rev.3: 34) c/, d/
1990	100.0	100.0	100.0	100.0	10.83	9.62	14.56
1991	95.7	94.1	103.9	100.9	11.18	9.90	15.23
1992	69.5	58.6	109.8	115.3	11.46	10.20	15.45
1993	53.1	36.3	112.9	120.0	11.74	10.45	16.10
1994	56.9	41.4	115.5	123.5	12.07	10.66	17.02
1995	59.7	45.3	117.7	126.3	12.37	10.93	17.34
1996	55.9	40.1	120.6	129.8	12.77	11.20	17.74
1997	46.3	27.1	124.5	133.1	13.17	11.49	18.35
1998	45.7	26.2	130.7	136.4	13.49	11.80	18.19
1999	40.9	19.7	136.3	140.1	13.85	11.40	18.45
2000	37.3	17.8	145.2	146.1	14.32	11.77	19.07
2001	31.5	15.1	148.8	150.8	14.76	12.18	19.62
2002	37.5	18.0	152.5	156.4	15.29	12.55	21.03
2003	43.9	19.0	156.2	163.4	15.74	12.80	21.66

Sources: United Nations Economic Commission for Europe (UNECE) and International Federation of Robotics (IFR).

a/ Source: OECD Economic Outlook, December 2003. Data for 2003 are estimated.

b/ Total compensation, blue-collar occupations. Source: U.S. Bureau of Labor Statistics. Data for 2003 are provisional.

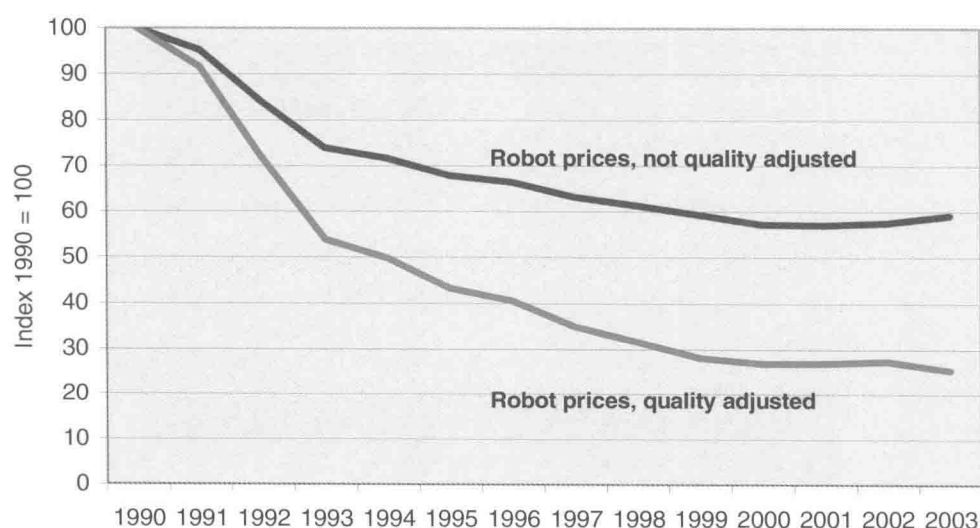
c/ Source: U.S. Bureau of Labor Statistics. Data for 2002 are provisional.

d/ Comprises three sub-industries which in 2003 had the following average hourly wages: motor vehicles \$28.03, motor vehicles bodies & trailers \$15.89 and motor vehicle parts \$20.42.

General note: The robot price indices calculated for individual countries are always based on prices of the same seven robot models supplied by four major international robot companies with large market shares in Europe and the United States.

Figure 3

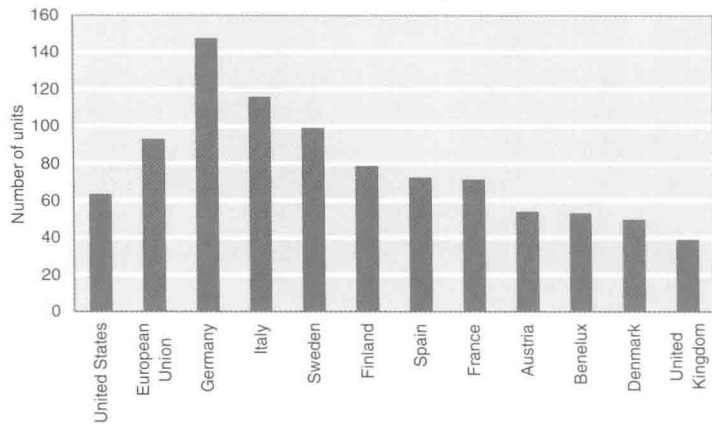
Price index of industrial robots for international comparison (based on 1990 \$ conversion rate), with and without quality adjustment.



	2003
Japan a/	322
Rep. of Korea b/	138
United States	63
European Union	93
Germany	148
Italy	116
Sweden	99
Finland	78
Spain	72
France	71
Austria	54
Benelux	53
Denmark	50
United Kingdom	39
Australia	36
Norway	24
Portugal	15
Czech Rep. a/	12

Sources: UNECE and IFR.

Figure 4 Number of robots per 10,000 persons employed in the manufacturing industry in 2003



	2001	2003
France	720	910
Germany	760	1,000
Italy	1,040	1,400
Japan	1,300	1,400
Spain	650	800
Sweden	560	560
United Kingdom	580	660
United States	640	740

Sources: UNECE and IFR.

Figure 5 Number of robots per 10,000 production workers in the motor vehicle industry, 2001 and 2003

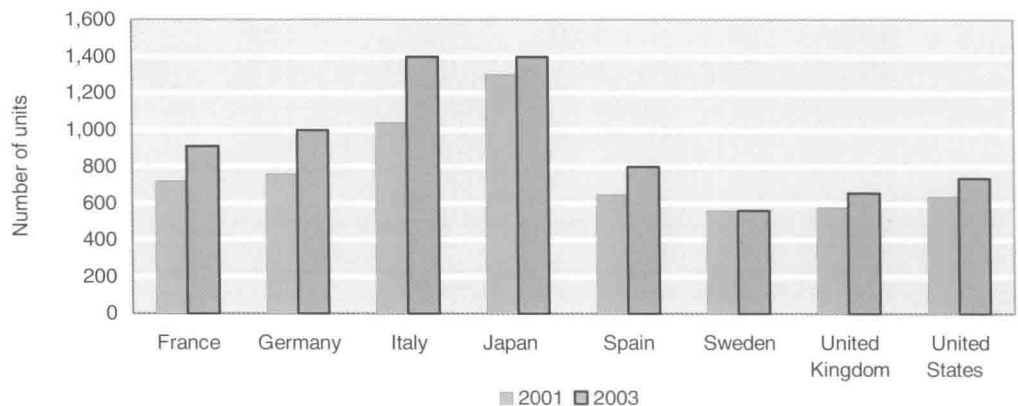


Table 3

Number of multipurpose industrial robots with 5 axes or more compared with the total number of multipurpose industrial robots in 2003. Ranking according to number of robots with 5 axes or more

	All robots	Robots with ≥ 5 axes	% share
USA	12,693	11,754	92.6
Germany	13,381	9,261	69.2
Italy	5,198	4,599	88.5
Rep. of Korea a/	4,660	2,819	60.5
France	3,117	2,566	82.3
Spain	2,031	1,708	84.1
United Kingdom	1,111	1,037	93.3
Sweden	386	378	97.9
Austria	365	269	73.7
Finland	387	267	69.0
Denmark	288	205	71.2
Norway	48	42	87.5
Subtotal	43,665	34,906	79.9
Japan	31,588		
All other countries	6,523		
Total	81,776		

Sources: UNECE, IFR and national robot associations.

a/ All types of industrial robots. About 16% of the robots are not classified by number of axes.

Diffusion of service robots

Table 4 gives details about the results of the UNECE/IFR survey of sales of service robots, broken down by application areas. As many companies did not provide market data, the figures reported here probably underestimate significantly the true sales amounts as well as the installed base of robots.

Service robots for professional use: 21,000 units installed up to the end of 2003

With 4,785 units, underwater systems accounted for 23% of the total number of service robots for professional use installed up to the end of 2003 (see table 4 and figure 6). Thereafter followed cleaning robots with 16%, laboratory robots with 15% and demolition and construction robots with 14%. Medical robots had a share of 12% and mobile robot platforms for general use accounted for 9%. Defense, rescue and security applications had a share of nearly 5% and field robotics, e.g. milking robots and forestry robots, 4%. The value of the stock of professional service robots is estimated at \$2.4 billion.

The unit prices for professional service robots differ significantly – from less than \$10,000 to more than \$300,000, depending on type of application. The most expensive robots are the underwater systems (\$300,000), followed by milking robots (\$200,000). The average price of a medical robot is about \$150,000.

Service robots for personal and private use: about 610,000 units for domestic use and almost 700,000 units for entertainment and leisure sold up to end 2003

Service robots for personal and private use are recorded separately, as their unit value is only a fraction of that of many types of service robots for professional use. They are also produced for a mass market with completely different marketing channels.

So far, service robots for personal and private use are mainly in the areas of domestic (household) robots, which include vacuum cleaning and lawn-mowing robots, and entertainment robots, including toy and hobby robots (see table 4 and figure 7). Sales of lawn-mowing robots have started to take off very strongly, with sales in excess of 40,000 units, and should continue to boom. The market potential is very large. Vacuum cleaning robots were introduced on the market at end of 2001. The market expanded rapidly in 2002-2003 and now counts at least 570,000 units.

Of the 610,000 robots for domestic household robots that were in use at end 2003 almost 400,000 were installed in 2003 (see table 4 and figure 7).

Projections for the period 2004-2007: 54,000 new service robots for professional use to be installed

Turning to the projections for the period 2004-2007, the stock of service robots for professional use is forecasted to increase by some 54,000 units (see table 4 and figure 6). Application areas with strong growth are humanoid robots, robots in public relation, laboratory robots, underwater systems, defense, rescue and security applications, professional cleaning robots and mobile robot platforms for multiple use. Medical robots, on the other hand, are not expected to do as well as was previously forecasted.

Projections for the period 2004-2007: about 6.6 million units of service robots for personal use to be sold

It is projected that sales of all types of domestic robots (vacuum cleaning, lawn-mowing, window cleaning and other types) in the period 2004-2007 can reach some 4.1 million units with an estimated value at \$2.7 billion (see table 4 and figure 7).

The market for entertainment and leisure robots, which includes toy robots, is forecasted at about 2.5 million units, most of which, of course, are very low cost. The sales value is estimated at over \$4 billion.