THE ROLE OF SMALL FIRMS IN THE DEVELOPMENT OF THE ROBOTICS MARKET IN SPAIN

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This paper studies the structure and development of the robotics market in Spain. The robotisation process of Spanish industry began in the bigger firms, but nowadays small and medium sized firms are the main adopters of robots. The degree of concentration of demand has decreased more than that of supply. The participation of robots in Spanish technology is still small although half the robots adopted are manufactured in Spain. The development of supply has been endogenous, but supplier firms share robots with other equipment in their product portfolio.

Keywords: robots, R&D, small and medium sized firms, technology adoption, Spanish industry.

INTRODUCTION

High technology firms are one of the most important sources of competitiveness for a country. These firms develop products and technologies that increase the productivity of the rest of the industrial sector, they use and promote R&D activities within the country's scientific and technological system, and improve the trade balance because they substitute imports and generate exports to less technologically developed countries.

The high technology sector in a country has various origins.[1] It can have its origin in the concentration of R&D centres in the public sector, in university spin-offs, in the installation of multinational firms, or in the transformation of existing industrial sectors in the country. In fact, it is difficult to find only one mechanism responsible for the origin and development of high technology complexes. On the contrary, more common is the existence of several mechanisms in each stage of the formation of the high technology sector.

Unlike in other countries, in Spain there are still very few empirical studies of high technology sectors, and in particular of sectors related to flexible automation technologies. These new technologies — numerically controlled machine tools, industrial robots, flexible manufacturing systems, etc. — are necessary elements to achieve organisational and technological integration in the area of design and manufacturing. Integration is one of the most important manufacturing strategies which firms have adopted during the eighties to compete in the market by cutting down on costs and increasing their flexibility.[2] Therefore, the introduction of advanced technologies into the industrial sector, together with the development of a supplying home industry, are two necessary criteria for estimating a country's technological competitiveness.

This paper studies the structure and development of a high tech market, namely the Spanish robotics market. In particular, the degree of concentration in the adoption of robots, the importance of small firms as dynamic elements in the development of this market, and the relationships between adopters and supplier firms are analysed. This paper has been compiled from an analysis of the whole population of Spanish robot adopters, and from the results of two surveys carried out by the author among robot adopter and supplier firms in Spain during the second half of 1990 and first half of 1991. The complete data of robot adoption in Spain are available up to 1992 because a specialist robotics journal, *Robotica*, assembled every year all the information about robot adopters directly from robot suppliers.

THE ROBOTICS MARKET IN SPAIN

The robotisation process in Spanish industry began in 1974, when the firm Seat had three Unimate robots installed in its car factory in Barcelona. Sixteen years later, in 1990, the total number of robots installed in Spain was 2,197. Table 1 shows the evolution of the robotics market in Spain during the 1980s. The real process of robotisation took place between 1981 and 1984 because during those years there was an intense robotisation of car manufacturing firms. This has turned the automotive sector into the most robotised sector of Spanish industry (Table 2). In that period, robots expanded to other industries too and from 1982 onwards the annual growth of robot population was over 300 units. The average number of robots in Spanish manufacturing industry in 1990 was 2.89 per firm, almost 50 per cent more than in 1987. Even if private car manufacturing firms are excluded, the automobile sector is the one having the greatest number of robots per firm, with an average of 6.56, followed by the motorcycle sector (5.62), glass (5) and electronics (3.86).

TABLE 1
EVOLUTION OF THE MOST DESCRIPTIVE VARIABLE IN THE SPANISH ROBOTICS MARKET

	1980	1982	1984	1986	1988	1989	1990
Population of robots	56	284	518	853	1420	1752	2197
Robots introduced each year	16	166	109	181	267	332	445
% population of robots annual variation	40	140	27	27	23	23	25
% robots with Spanish technology	0	0	0	2.0	2.3	3.3	4.1
Total robotised firms	19	30	48	180	278	341	421
First time robotised firms	7	6	12	79	36	63	80
Demand concentration (CI16)[a]	0.96	0.93	0.86	0.67	0.63	0.59	0.57
Robotisation rate[b]	0.18	1.04	2.10	3.48	5.37	6.41	8.05

[a] CI16 represents the proportion of robot population of the 16 most robotised Spanish firms.

[b] The robotisation rate is worked out as the number of robots installed per 1000 workers in manufacturing industry.

Source: Own Calculations.

TABLE 2
ROBOTISATION RATES IN SPANISH MANUFACTURING INDUSTRY[a]

Industry	1986	1988	1989	1990
Automotive industry	36.93	51.94	57.24	64.01
Machinery and metal transformation	7.05	8.57	10.66	13.72
Other transport equipment	2.73	5.13	6.59	7.64
Electronics and office machines	0.73	2.70	3.70	8.36
Electrical machinery and material	0.84	1.50	1.54	1.58
Rubber transformation and plastic material	—	0.65	2.33	3.12
Paper and printing	—	0.06	0.06	0.06
Food processing	0.03	0.05	0.10	0.12
Wood and cork	—	0.04	0.04	0.04
Total manufacturing industry	3.48	5.37	6.41	8.05

[a] The robotisation rate is worked out as the number of robots installed per every 1000 workers in each industry.

Source: Own calculations.

Industrial robots increase productivity and industrial production quality. According to the survey made among the robot adopter firms,[3] the main reason for the introduction of the first industrial robot was to increase the firm's technological experience in new technologies. Some 54 per cent of the surveyed firms already had experience in automation — mainly in numerically controlled machine tools and programmable machines — and all the surveyed firms were aware of other firms' experiences. However, the objective of the introduction of the first robot into each firm was initially to learn about this new technology. Apart from this objective, the other three main motivations were the improvement of working conditions and safety, the reduction of labour costs and the increase in manufacturing and product quality.

In 1982 the automotive industry contained 84 per cent of the robots installed in Spanish industry, this sector being the major adopter of robots, making between 70 per cent and 90 per cent of all investments. Since 1986 the automotive industry has kept buying, on average, 50 per cent of the robots sold in Spain yearly. Other adopter industries have joined the robotics market. In 1990, the industry with the second largest degree of robotisation and number of robots installed was the metalworking industry, but with a robotisation rate six times lower than that of the automotive industry. After these two sectors, the Spanish industries using robots on a bigger scale are electronics, motorcycles, plastics and domestic appliances. These six industries together account for 87.4 per cent of the population of robots in Spain.

When robot distribution in Spanish industry is compared with that of other countries with a similar industry structure, such as France or Germany, it can be concluded that there has been less diversification into different sectors in Spain. The Spanish robotics market was starting to extend beyond the automative industry only in the very late 1980s and early 1990s, while, in those other countries, this had already taken place. Similarly, Table 3 indicates that the new robot applications of

the 1980s, such as assembly or machine feeding, were still in the early stages of diffusion in the Spanish industry at the end of that decade.

TABLE 3
ROBOT APPLICATION DISTRIBUTION IN DIFFERENT COUNTRIES IN 1989

	Spain	Germany	France	Japan	Norway
Welding	56.97	35.03	35.39	21.60	22.91
Handling	14.01	17.04	14.14	n.a.	14.60
Assembly	8.10	18.76	13.46	33.41	10.75
Machine feeding	3.45	10.28	10.60	6.39	9.94

Source: Own calculations.

In Spain, as in other countries, high concentration is one of the characteristics of the robotics market. For instance, in the US, ten plants had one third of all the robots installed in the country in 1988. Of these, 80 per cent were used in welding and manipulation processes.[4] In Spain, the twelve firms having the greatest number of robots installed in the whole country contained 54 per cent of the population of robots, all foreign. The total number of firms that had adopted at least one robot up to 1990 was 421, whereas in 1980 there were only 19. With the diffusion of robotics to industries other than the automotive industry, the degree of concentration in robotics has decreased. Four firms, all automobile manufacturers, with the largest number of robots installed in 1982, accounted for 81.7 per cent of all the robots installed in Spanish industry. By 1990 this concentration rate had decreased to 40 per cent, and the concentration rate of the sixteen most robotised firms had dropped from 92.6 per cent in 1982 to 56.8 per cent. A similar evolution has taken place in the concentration of the annual supply of robots. Among the firms introducing the greatest number of robots, the automotive industry was long predominant. However, since 1985 the metalworking, electronics and machinery industries have topped the ranking. The decrease in the degree of concentration of robots is the result of the decrease in size of the adopter firm, as shown in Table 4.

TABLE 4
DISTRIBUTION OF ROBOTS AND ROBOT ADOPTERS ACCORDING TO FIRM SIZE IN 1990[a]

	Including the automotive industry				Excluding the automotive industry			
	% firms	% robots	NRE[b]	IR[c]	% firms	% robots	NRE[b]	IR[c]
Large	35.98	77.51	14.25	7.22	33.33	46.84	4.11	3.46
Medium	39.79	15.95	2.65	21.89	41.31	37.67	2.67	21.97
Small	24.23	6.54	1.78	56.56	25.37	15.49	1.78	56.56

[a] To preserve confidentiality, firms accounting for 12 per cent of the population of robots in 1990 have not been included in this table. Size classification is based on the number of employees in small firms (1-49), medium sized firms (50-249) and large firms over (250). Data on employees have been obtained from the Yearbook, *Las 25000 Empresas Españolas* by Fomento de la Producción, and through telephone calls to the firms. The research and training sector has been excluded.

[b] NRE is the average number of robots per firm.

[c] IR is the number of robots per 1000 employees.

Source: Own calculations.

ROBOT ADOPTION AND FIRM SIZE[5]

One of the most interesting economic issues, as far as research is concerned, is the relation between firm size and the adoption of new technologies (NT). Some studies indicate that it is small firms that play the lead in the adoption of NT: for example, in the Canadian auto parts industry, small and medium sized firms are more automated than the bigger ones, among other reasons because their directors, being more directly involved in the manufacturing process, are more aware of the opportunities NT provides.[6] However, there is a larger number of studies indicating that it is the big firms that adopt NT on a larger scale. Among others, the study of Cainarca *et al.*[7] on the diffusion of CAD/CAM equipment in Italian manufacturing industry shows that its adoption is more probable in big firms and plants, mainly in plants which belong to big industrial groups.

Nevertheless, two variables have to be introduced in the relation between firm size and NT adoption: first, the investment volume NTs require, and, second, time evolution. With respect to the first variable, non-easily divisible technologies, such as a flexible manufacturing system (FMS), will constitute an obstacle for the small firm's limited resources. On the other hand, technologies that can be applied on a small scale, such as industrial robots, and are optimised with a medium production volume, will hopefully not be an obstacle for small firms. For example, in Germany 60 per cent of FMS are installed in firms with more than 1000 employees, whereas the numerically controlled machine tools (NCMT), which require much less investment than FMS, are installed in small and medium sized firms.[8] The second variable, time evolution, implies that in the first stages of NT diffusion it is the big firms that, owing to their greater economic and technological resources, are in a better position to overcome the risk and problems a still non-mature technology presents. Once the NT matures, firm size becomes less relevant.

The existing literature demonstrates this behaviour. For instance, in the case of NCMT it was the big firms that initially adopted this NT to a large extent. Nowadays, however, in Japan as well as in the USA, small and medium sized firms constitute the main part of the NCMT market.[9] Acs, Audretsch and Carlsson have also analysed the relation between firm size and the adoption of NCMT over several years, and they find that the implementation of NCMT has been associated with a progressive decrease in the average size of the adopter firm.[10]

Therefore, in the study of the relation between firm size and the adoption of robots in Spain, the time dimension has to be considered. Table 4 indicates that in 1990, 77 per cent of the robots in Spain were concentrated in large firms (those with over 250 employees) — down from 95 per cent in 1982. Excluding the automotive industry, the percentage of the population of robots installed in large firms in 1990

was 47 per cent. Most — 53 per cent — were installed in small and medium sized firms (those with fewer than 250 employees). Since the robot is one of the flexible automation technologies that adapts to medium production volumes, most of its adopter firms — 41 per cent — are medium sized. The first robot adopters in Spain were large firms, but nowadays small and medium sized firms represent the majority of the new robot adopters. Thus, in 1980, medium sized firms accounted for 28 per cent of the new robot adopters, 37 per cent in 1986, and 51 per cent in 1990. As for small firms, there were no new robot adopters in 1980 or 1984, but these firms were responsible for 16 per cent of the new adopters in 1986, and 42 per cent in 1990.

In Spain, robots are diffusing more and more in the small and medium sized firms, which is what happened with other NT, such as NCMT. Of all the robots installed in Spanish industry in 1984, excluding the automotive industry, 70 per cent went to large firms. In 1988 this dropped to 37 per cent and to 28 per cent in 1990. Small firms did not buy any robots in 1984, but did buy 10 per cent of robots in 1986 and 23 per cent in 1990. It is noteworthy that, excluding the automotive sector with its purchase of 40 per cent of all robots in Spain, small and medium sized firms have purchased between 50 per cent and 65 per cent of the rest of the robots over the last few years. A similar process has been experienced in other countries: for instance, in France large firms (those with over 1000 employees) bought 82 per cent of robots in 1983, but only 64 per cent in 1989.

Finally, Table 4 shows that the average robotisation rate of small firms is more than twice that of medium sized firms, and almost twenty times that of large firms. Excluding the automotive sector, in 1990 large firms had on average of 3.46 robots for every 1000 employees, medium sized firms had 21.97 and small firms had 56.56 robots. However, the average number of robots per firm was 1.78 in small firms, 2.67 in medium sized firms, and in large firms the ratio was 4.11, which goes up to 14.25 if the automotive sector is included. This higher concentration in big firms is experienced in other countries, although it is not the only possibility. For example, in 1984 the robotisation rate of Japanese firms with less than 30 employees was twice that of all manufacturing industry. Japan went through a shortage of young workers, mainly in big firms, and the introduction of robots helped maintain economic growth rates.

THE STRUCTURE AND DEVELOPMENT OF THE ROBOTICS INDUSTRY IN SPAIN

The Spanish robotics supplier firms have three kinds of origin:

1) manufacturing firms — national firms or foreign firm subsidiaries — of electrical and tool machinery, which have incorporated industrial robots in their product portfolios;
2) engineering firms whose main line of business is industrial design and whose projects include the integration of automation equipment

bought from the manufacturer, or which subcontract specialised firms to manufacture this equipment; and

3) subsidiaries of foreign robotics manufacturers settled in Spain with the purpose of manufacturing and/or marketing robots and other automation equipment developed abroad.

The first two kinds of origin are endogenous development of robotics supply, whereas the third kind is exogenous development. Of the 32 robot supplier firms existing in 1990, 25 are the product of endogenous development and the rest (7 firms) are subsidiaries of foreign robotics manufacturers settled in Spain, mainly in the late eighties. Of the 25 firms, 11 are engineering firms, non-manufacturing, which subcontract other firms or their head office for the manufacturing of the projects they carry out. Engineering firms were the first to supply robots, followed by electrical and machine tool firms, and finally by subsidiaries of foreign robotics manufacturers settled in Spain in the late eighties. There have also been firms — eight firms until 1990 — that have left this market owing to cost reasons: it was not profitable for them to compete with other manufacturers or suppliers with bigger production capacity, so either they have ended up by transferring their technology or cancelling the trading agreements they had with foreign manufacturers.

Supplier firms have developed in the chief Spanish regions, that is to say, in those regions with higher levels of economic and technological infrastructure. Out of the 32 robot suppliers, 29 firms are located in the chief regions — Catalonia (19 firms), Madrid (5 firms) and the Basque Country (5 firms) — these being the oldest firms in the industry. Only since 1989 have suppliers' locations extended to other regions; in fact, three new firms have been installed in these regions. A survey was posted to all suppliers. It was answered by sixteen firms, responsible for 92 per cent of all the robots installed in Spain in 1990.[11] One of the aims of this survey was to discover the robot suppliers' location criteria.

The criteria considered really important (Table 5) were proximity to clients, the existence of a good communication network, and the existence of qualified personnel in the area. This set of criteria surpasses the national average in those regions where robot supply is concentrated, namely the central regions of Catalonia, Madrid and the Basque Country. Furthermore, in these three regions 78 per cent of the population of robots is concentrated, excluding the automotive industry. Thus the surveyed industries are located in these same regions, where the robotics market has been created. Similar economies of agglomeration to the ones existing in the electronics and computer industry in southern England and Silicon Valley appear in these areas.[12] Less important location criteria were proximity to suppliers and the low cost of installation in the area. An unimportant criterion was the existence of universities nearby, which reflects the sparse relations these firms have established with universities.

TABLE 5
REASONS FOR THE LOCATION OF ROBOT SUPPLIERS IN SPAIN

Location Factor	Value[a]
Proximity to customers	2.19
Transport convenience (motorways, airports, etc.)	2.12
Plenty of skilled personnel in the area	2.00
Personal reasons (founders lived or worked in the area)	1.93
Prosperity of the province	1.86
Presence of universities and research centres	1.75
Proximity to suppliers	1.62
Low cost of installation in the area	1.49

[a] Scored on a scale of 1 (unimportant), 2 (important) and 3 (very important)

Source: Own calculations.

The endogenous development of the robot supplier industry indicates that most of these firms are dependent on local capital: of the 32 firms, 20 have sprung from local capital, which means 62.5 per cent of the whole number of firms. Firms built on foreign capital are mainly small sized firms, whereas firms built on local capital are bigger in size, on average. Of the total, 25 suppliers are small firms — they have less than 50 employees — three are medium sized firms, and four are large firms with more than 250 employees. Of the four large firms, only one is dependent on foreign capital. Most foreign firms have been recently created and some of them keep only a minimum infrastructure in Spain, remaining dependent on their head office technicians abroad for the development and installation of robots.

However, although the robot supply industry is essentially made up of small firms, only a few firms concentrate the majority of robot sales in Spain. For example, in 1990, four firms sold 80 per cent of the 402 robots installed in Spain during that year, a similar concentration rate to that in the eighties. Fewer than five robots per year are installed by 40 per cent of firms. No relation between firm size and sales or concentration rate has been observed.

What has been observed is an evolution towards a more technical and more diversified supply. In 1985 the average robot supply was 4.2 models per firm, whereas in 1990 it had increased to 6.4 models (Table 6). Also in this period the percentage of firms supplying a larger variety of robots increased: in 1985, only 18 per cent of firms supplied more than six different robots, and in 1990, 44 per cent did. Since the percentage of firms with fewer than two different models of robots has decreased, and the average number of models and the percentage of firms with more than six models have increased, we can conclude that robot supply in Spain has become more diversified. This result reflects partly the technical evolution experienced by industrial robots, which has enabled them to perform more functions, and partly the diversification of supplier firms to integrate robots into new industrial sectors which have

never used robots before. Firm diversification is a consequence of sector diffusion and technical progress.

TABLE 6
EVOLUTION OF ROBOT SUPPLY IN SPAIN

	1985	1987	1990
Number of models in the market	92	128	209
% Spanish models	4.3	6.2	7.2
Average number of models per firm	4.2	5.3	6.4
% of 1 or 2 robot supplier firms	54.5	45.8	25.9
% of 3 up to 6 robot supplier firms	27.3	33.3	29.6
% of 7 or more robot supplier firms	18.2	20.9	44.5

Source: Own calculations.

Although diversification of supply has increased, the percentage of firms in which robots represent a significant sales percentage is very small. In 22 of the surveyed firms, robot sales in 1990 represented less than 25 per cent of total sales. Only one of the surveyed firms — a foreign firm — was fully devoted to robot installation. The few other firms with more than 90 per cent of sales from the robotics market are small firms dependent on local capital. Most firms in the robotics market import and market robots. According to the survey, 87 per cent of firms do this; 31 per cent of firms have their own licence for manufacturing robots and 6 per cent manufacture robots under foreign licence. A firm would normally specialise in only one specific activity, but four firms out of those surveyed had two activities at the same time, namely robot manufacturing under their own licence and foreign robot importation. Taking these data into account, the origin of the robots installed in Spain in 1990 was as follows: 53 per cent were imported robots, 37 per cent were licensed and made in Spain, and 9 per cent were manufactured under foreign licence. Some 46 per cent of the robots installed in Spain in 1990 were made domestically. However, only 7 per cent of all the robots installed in Spain are made with Spanish technology. Sweden, the United States, Japan and France are the countries which provided the original technology in most of the cases.

The surveyed firms declared that it is their technical capacity and after-sales service which enable them to compete in the market (Table 7). This result agrees with the one obtained from the robot adopter firms survey, as 84 per cent declared that the choice of their supplier had been based on the supplier's technical capacity, and 13 per cent on the supplier's after-sales service. Only 2 per cent of the adopter firms considered financing to be the primary purchase criterion. The need for high technical capacity to meet the clients' requirements makes it necessary to invest in R&D. However, because of the presence in the market of foreign robotics firms, which develop R&D in their head offices abroad, and because 53 per cent of the robots installed in Spain are imported, R&D intensity in this market remains low.

TABLE 7
CRITERIA FOR CHOOSING A ROBOT SUPPLIER

Criteria	Value[a]
Technical capacity	3.56
After sales service	3.44
Former clients' references	2.87
Geographical proximity	2.54
Advertising, previous contacts with the firm	2.25
Financing, form of payment	2.06

[a] Scored on a scale of 1 (not important) to 4 (very important)

Source: Own Calculations

Table 8 shows that in 1990 the surveyed firms' expenditure on R&D represented less than 4 per cent of their sales, a percentage that contrasts with that in, for example, Japanese and US supplier firms in 1985, which was 10 per cent and 17 per cent respectively. In these countries, home robot production is clearly larger than robot imports. These countries house the main world robot manufacturers, which are bigger in size and older than the largest Spanish robot supplier firms. Small and medium sized firms make a greater research effort than large firms (Table 8), as well as a greater marketing effort. The small supplier firms surveyed invest 4.3 per cent of their sales in R&D and 3.5 per cent in marketing, whereas the percentages for large firms are 3.2 per cent and 1.4 per cent respectively. This pattern exists for Japanese and North American firms too.

TABLE 8
R&D EFFORT IN THE ROBOTICS INDUSTRY[a]

	Spain	Japan	USA
Large	3.22	9	17
Small and medium	4.34	12	21
All firms	3.68	10	17

[a] Data for Japan and the USA are from 1985 and those for Spain are from 1990. In the United States, a small and medium robot supplier is one with 1984 sales below $5 million; a large one has 1984 sales of $5 million or more. In Japan, a small and medium robot supplier is one with 1983 sales below 800 million yen; a large one has 1983 sales of 800 million yen or more. In Spain, large firms are those with 250 or more employees, and small and medium sized firms are those with fewer than 250 employees.

Source: Own calculations and E. Mansfield, 'Technological change in robotics: Japan and the United States', *Managerial Decision Economics*, special issue, 1989, pp.19-25.

All these considerations — relatively low investment in R&D, low market share of robots in the product portfolio, high market quota of imported robots — partially account for the other two results of the survey. The first is that only two out of the 16 surveyed firms have taken part in public research projects related to industrial robotics, in spite of the fact that funds were available from various national and EEC

R&D programmes. These two firms spring from local capital and have invested twice as much in R&D as the rest of the firms analyzed. The second result is that links with universities are weak. Only 25 per cent of the surveyed firms have taken part in R&D projects with universities.

In the Spanish robotics market, there are close relations between suppliers and clients. The client-supplier interaction is a key factor in the success of the introduction of advanced manufacturing technologies since the suppliers are the ones who present the new technology to the adopter firms, the ones who talk firm directors into the adoption of the new technology by presenting its advantages, the ones who train the personnel using the new technology, and the ones who solve the problems and adapt the productive environment to the needs of the new technology.[13]

This interaction exists in the Spanish market since 75 per cent of supplier firms have performed viability studies and conducted training courses for all their clients. During the introduction of the robot, there were frequent and regular meetings with the majority of the adopter firms. The smaller the adopter firm, the more intense the interaction that exists. For instance, the surveyed supplier firms have carried out maintenance jobs on the robots installed in small firms which did not have the skilled personnel and technical means necessary for the maintenance of automation technologies. The big adopter firms have not needed the supplier's maintenance because they already have their own skilled personnel, capable of doing maintenance jobs.

As for the need for training, both small and large firms have needed some training for the introduction and use of robots. All the surveyed adopter firms had workers who had attended training courses, with 30 hours of training on average. Two out of the sixteen surveyed suppliers reported that at first some of the adopter firms had turned down the training courses offered on the grounds that they were not important. However, problems arose and training became necessary. Training is almost exclusively up to the supplier because, to a large extent, the adopter firms are unaware of the possibilities an industrial robot has. It is in the training process that they become aware of the benefits of advanced manufacturing technologies. For example, the Spanish adopter firms that had taken longer training courses had also, thanks to robotics, increased their flexibility in making product changes. It is also noteworthy that half of the adopter firms which complained about their training did so on the grounds that the courses were shorter than was really necessary.

CONCLUSION

Initially, robot diffusion in Spain was carried out in large firms. In 1980, 71 per cent of the new Spanish adopter firms were large firms and in 1984, 70 per cent of the robots introduced were installed in large firms.

But during the 1980s the percentage of small and medium sized firms among the new adopting firms and the new robots installed has been increasing. It now stands at more than 60 per cent. Consequently, the demand concentration rate went down from 98 per cent in 1982 to 59 per cent in 1990 for the sixteen firms that bought the most robots during those years.

Supply concentration has not decreased as much as that of robot demand. In 1990, four out of the 32 Spanish suppliers sold 80 per cent of the robots. Supply has concentrated in the major regions, where firms have found economies of agglomeration together with the proximity to the markets for robots. The development of the supply sector has been endogenous: the first supplier firms were Spanish engineering firms, joined later by machine tool and/or electrical machinery manufacturers, either Spanish or foreign. From the mid 1980s onwards, subsidiaries of foreign robot manufacturing firms entered the market. It is small firms, and not large firms, that have developed the robotics industry in Spain.

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