THE INTERRELATION BETWEEN R&D AND TECHNOLOGY IMPORTS

The situation in some OECD countries

CONTENTS

This paper was prepared by Dr Luis Rodriguez-Romero, Professor of the University Carlos III (Madrid) and Dr M. Paloma Sanchez, Professor of the Autonomous University of Madrid. It was presented at the 52nd meeting of the Committee for Scientific and Technological Policy in November 1989 in the context of a Forum Discussion, and has subsequently been revised for publication.

SUMMARY

Domestic R&D and imports of foreign technology through various channels are different ways of accomplishing technical change for a country. The object of this paper is to show how some OECD countries balance both, and to underline that the acquisition of foreign technology and its diffusion throughout a country do not give rise to real transfers of know-how, and therefore to stable technological development, unless accompanied by a reasonably high level of domestic R&D. If this is the case, although diffusion policy measures have to be implemented, the encouragement of business R&D should not be neglected. The Spanish case illustrates a very unbalanced situation, where too many resources have been devoted to importing foreign technology to the detriment of R&D effort. A conceptual and statistical analysis is made, showing the scarcity of detailed sectoral indicators useful for international comparisons.

I. INTRODUCTION

Although both R&D and transfer of technology activities have been dealt with extensively in the past, there are not many studies of their inter-relations. The aim of this paper is to explore the topic and data for some OECD countries. These data show major differences among OECD countries and suggest that policy approaches and measures should be taken according to national circumstances.

Some of the points made in earlier work are appropriate to introduce our discussion. These are[1]:

a) There is usually a distinction between i) creation and development of new technology; and ii) diffusion of this technology within a country and between countries[2]. Diffusion is sometimes considered the logical consequence of creation and development but this is not always true. They are governed by different factors and the policy measures to encourage them are usually different.

b) The creation and development of new technology, and the production of innovations, is crucial if an industry or a country aims to be a leader in its field. The adoption of already developed technologies means assuming the role of follower in the technological process. But for the individual firm or country both creation and adoption give rise to technological change.

c) The creation of technology has a positive impact on competition; however, the overall effect on economic activity is greater if widespread diffusion takes place. Inadequate diffusion could be one of the reasons for the productivity paradox discussed in an International Seminar held at the OECD, in June 1989 and partly published in *STI Review* Nos 7 and 8. The pervasive effect of diffusion is, for example, very clear in the case of information technology. However, there is not enough empirical evidence regarding technological diffusion itself, nor accurate measures of its effects on economic activity.

d) We have a widely accepted indicator for the creation of technology – R&D resources – although we are increasingly aware of its shortcomings[3]. The same cannot be said for diffusion. The rate of investment determines the incorporation of technology in the production process, but that incorporation can follow several paths: including, in machinery and equipment (embodied technology) or licensing and technical assistance (disembodied technology) and other kinds of intangible investments. A proxy for international diffusion of the former could be the trade in high technology products, and for the latter international technological payments. There are few of these indicators at domestic level, and fewer still at international level and for diffusion of disembodied technology. There are many methodological problems to overcome at international level before comparable data can be collected.

Given this situation, scientific policy to support R&D is understood as a means of increasing creation and development of technology, while other measures such as promoting technological trade are supposed to increase domestic diffusion and application of foreign technology.

No country can opt for creation or diffusion exclusively. To rely only on domestically produced technology is not rational or feasible, but to concentrate mainly on diffusion and use of foreign technology leads to technological dependence. An adequate balance between them, both on a sectoral and global basis, should be achieved. The emphasis recently put on diffusion, the need to promote it and establish public aid to encourage it, could lead small or less developed countries to relax their R&D effort with a risk of increasing their technological gap. This stance is appealing as the R&D budget can be reassigned to other seemingly more urgent needs, but it will obviously prejudice future technological development.

One key point regarding diffusion is that this process involves far more than the simple introduction of new machinery or simple patent licensing. Reorganising factory work and materials flow may be needed together with improved management practices and additional training for the labour force. If disembodied technology is to be introduced, more labour force skills (also important for applying domestic R&D), are also necessary, and efforts to assimilate and eventually improve the technology may have to be made. Furthermore bought-in technology must be adapted to the characteristics of the company and the market it is supplying.

Changes to achieve real transfer of know-how may be the responsibility of the R&D department or other departments within the company. The assignment of such activities is a question of internal organisation that varies from one company to another. Nevertheless, it is more than a conceptual problem. If there is a R&D laboratory, it indicates that the firm carries out research on a regular basis, and the diffusion process is more likely to be complete with all complementary steps taking place. Furthermore, the mere existence of research enables the company to know its technological needs better and the bought-in technology will probably complement existing technology, or technology being developed. In other words, the greater knowledge the company has implies a decreasing uncertainty when dealing with technological markets, and it will be in a better position to judge what it wants and what it is paying for.

If this is true, policy measures to encourage industrial R&D should also increase diffusion. Moreover, if an adequate level of industrial R&D does not exist, effective domestic diffusion and real transfers of technology will hardly take place. In this case the technological level of the company will be based on outside technology, creating never-ending dependence. This argument may be extended to apply to the whole country.

II. METHODOLOGICAL AND STATISTICAL PROBLEMS

The main methodological and statistical problems in measuring the interaction between R&D and technology imports are due to the lack of satisfactory comparable indicators.

Research and Development

As is well known there are many conceptual difficulties in measuring R&D. The revision of the "Frascati Manual" (*Proposed Standard Practice of Surveys of Research and Experimental Development*, 1980) will probably help. Two points can be stressed here. First, companies should use the same methods to measure R&D, because at present there are enormous discrepancies in the accounting of their R&D costs. Quite often tax considerations influence these measurements, which obviously introduce disturbances for purposes of comparison. Second, there is a need for in-depth conceptual study of these essential activities. Real diffusion of bought-in technology, both embodied and disembodied, does not take place without R&D activities. There should be a clearly distinguishable line between what is R&D and what is not, in order to measure the research effort and ultimately define policy measures better.

Diffusion

Some of the problems concerning diffusion indicators are:

Definition of High Technology Products

The definition of high technology products is usually based on the amount of R&D which goes into a particular product compared with sales or value added, but there are problems of interpretation[4]. No matter how large the original amount of R&D, it can be bought from outside the firm. That is, firms can be producing a high technology product without making any R&D effort at all. This is, for instance, the situation in some Spanish industries, which have increased their exports of high technology products in recent years, but in large part this has been due to the import of disembodied technology.

Technological Balance of Payments

There are many conceptual problems in defining the scope of the technological balance of payments (TBP). In many countries the data differ according to the source of information. Large discrepancies are noted between information obtained from a questionnaire, and information received from a state department, such as the Central Bank, the Exchange Control Department or industry authorities.

Another difficulty when using TBP data is that the sectoral classification is often different from the one used for R&D statistics. Thus, comparable sectoral analysis becomes a hard task. Furthermore although R&D-intensive sectors and technology import-intensive sectors may coincide, this does not necessarily mean that the technological activities complement each other at company level. Within a particular sector companies may produce their own technology, companies may acquire all their technology from outside, and others may balance the two and do both. Therefore, a further breakdown is needed to get an accurate picture. It would also be useful to have reliable indicators on the share of R&D to create and develop new technology and the share devoted to assimilate imported techniques. This latter refers to R&D activities needed for real diffusion.

Finally, if the payments for R&D abroad[5] are included in the technological balance of payments, a clear statistical differentiation of such payments should be made. The effect on its technological level of research expenditure outside the country contracted and performed for national firms differs greatly from other technological payments. Therefore, although included in TBP it is important for analytical purposes to distinguish these two.

III. DOMESTIC R&D AND FOREIGN TECHNOLOGY TRANSACTIONS IN SOME OECD COUNTRIES

As it has been said, domestic R&D and international technology are not exclusive alternatives for a given country. All countries use a mix of research activities and technology imports to achieve technological change and only differ in their relative use of one or the other. Similarly technology exports and imports are often concentrated in the same economic activities – or even in the same firm – but their relative balance is important in determining long-term outcomes.

Two different national indicators are commonly used for R&D. One is business enterprise expenditure on R&D (BERD) and the other is gross domestic expenditure on R&D (GERD). As one of the main objects of this paper was to compare the technological effort of different economic sectors, the first indicator seemed more suitable and is used in Tables 1 to 4. However in order to give a more complete picture, Figure 1 and Table 5 show relative weights of R&D, payments for technology imports in TBP and imports of high technology products. As the breakdown by sectors of the latter was not available, a global comparison could only be made and GERD was used.

The comparison between business enterprise R&D expenditure (BERD), technology payments and technology receipts in some OECD countries contributes to understanding the complementarity between them and gives an idea of the diversity between countries. The data used in this comparison were provided by the Directorate for Science, Technology and Industry of the OECD

and they refer mainly to 1986[6]. Apart from some chronological disparities, two basic and unavoidable deficiencies in these data should be kept in mind, with potential effects on the results obtained:

a) In most countries, BERD and technology transaction data are collected by two different and independent organisations, resulting in a large number of sectoral and methodological discrepancies which demand manipulation of data to make them comparable nationally;

b) International disaggregated comparisons require further data manipulation, mainly of BERD data which are usually more disaggregated than technology transaction data.

The final result is that for some countries included in our analysis totals obtained through sectoral aggregation of the data differ slightly from national totals derived from the *OECD Main Science and Technology Indicators* (MSTI). In these cases, we have used the MSTI data for global analysis, and the sectoral data provided directly by OECD for disaggregated presentations.

Table 1 shows the total payments and receipts, the derived technological transaction balance and BERD for the nine countries included in our sample. In the year studied, only the US and Sweden show a surplus in their international technological transactions. There is a deficit for the other countries. The coefficient payments/receipts shows the diverse deficit intensity in each country. At the upper end of the scale are Spain and Australia, where technology imports are respectively 315 per cent and 160 per cent larger than technology exports. At the lower end are France, Canada and Japan where technology imports represent only 20 to 30 per cent more than technology exports. In an intermediate position are Germany and Italy with technology imports almost double technology exports.

If we compare the results obtained here with those derived from a previous OECD study for 1978[7] the dynamic aspects of the relationship between payments and receipts can be appreciated and this suggests that suitable policies can improve this relationship. As can be seen by comparing the last two columns in Table 1, the most remarkable case is the improvement of Italy, decreasing its foreign dependence. Japan, Germany and Spain follow the same trend with a lower intensity, while the two least dependent countries in 1978, the US and France, increased their dependence.

However, payments and receipts derived from foreign transactions only provide a limited picture of domestic technological capacity. As a second dimension, Table 1 presents the technology payments/BERD coefficient with the aim of capturing the relative use of domestic and foreign sources of technological change. The technology payments/BERD coefficient (column 5, Table 1)

Table 1

Domestic R&D and foreign technology transactions

Millions $

		Total payment	Total receipts	Technology transactions balance	BERD	Payments/ BERD	Payments/ receipts	For comparison payment/receipt 1978 (C. Antonelli)
US	(1986)	7 007.00	19 701.00	12 694.00	80 629.00	0.087	0.356	0.104
Japan	(1987)	1 958.28	490.42	–467.86	44 895.83	0.044	1.314	1.574
Germany	(1985)	1 207.82	615.31	–592.51	12 317.01	0.098	1.963	2.251
France	(1986)	1 368.83	1 138.24	–230.59	9 595.82	0.143	1.203	1.080
Italy	(1988)	1 178.34	638.35	–539.99	6 000.67	0.196	1.846	5.132
Canada	(1986)	541.01	425.18	–115.83	2 753.96	0.196	1.272	
Spain	(1986)	741.28	178.46	–562.82	787.85	0.941	4.154	5.530
Sweden	(1987)	51.42	149.37	97.95	3 217.82	0.016	0.344	
Australia	(1986)	184.80	70.93	–113.87	792.67	0.233	2.605	
Weighted mean						0.088	0.583	
Arithmetic mean						0.255	1.639	

Source: Data from OECD and Antonelli, C., p. 4 (see Note 7). The data provided by OECD were most recent year available.

shows that, in general, foreign technology payments represent only a small share of domestic R&D effort. Spain is the exception as the amount of resources devoted to BERD is very similar to foreign technology import payments. The most domestically oriented countries, Japan and Sweden, devote less than 5 per cent of their R&D expenses to technology imports while in Italy, France and Australia this climbs to more than 15 per cent. Germany and the US appear as intermediate cases with import payments of less than 10 per cent of BERD.

Combining the two dimensions considered, we can classify our sample of countries into four groups according to domestic BERD and foreign technological transactions (Table 2):

a) In group A three countries appear with a very favourable technological balance and marginal foreign technological imports in relation to their domestic R&D effort. The presence of Japan in this group should be underlined as it historically relied on foreign technology imports, but this situation has dramatically changed.

b) In contrast, there are three countries in group D with a large deficit in technological transactions and very heavy foreign technology imports as a source of technological change.

Table 2

Grouping countries by domestic R&D and foreign technology transactions

	Payment/BERD < $\bar{y}$	Payment/BERD > $\bar{y}$
Payments/receipts < $\bar{x}$	US Japan Sweden A	France Canada B
Payments/receipts > $\bar{x}$	Germany C	Italy Spain Australia D

$\bar{x}$: Arithmetic mean; $\bar{y}$: Weighted mean.
Source: Derived from Table 1.

c) Group B represent one of two possible intermediate cases, presenting a strong technology export capacity jointly with a large contribution of technological imports compared with domestic R&D.

d) Finally, group C is an example of countries with a larger than average deficit in their technological transactions but strong domestic R&D.

The variation at international level regarding the balance of R&D and technological transactions is also reflected at national level, and shows a wide variety of sectoral situations (see Appendix 1). The highest and lowest values of the two coefficients used are shown in Tables 3 and 4, showing some similarities across countries together with major differences between them.

Transport equipment is the activity with the lowest technology payments/ BERD ratio across countries. The strong domestic technological capacity and the absence of foreign technological transfers through licensing and similar transactions in this sector is reflected in low ratios of technology payments/ BERD.

Differences between countries are however very noticeable, as five different sectors occupy the weakest position with the highest technological payments/BERD ratios. Three countries (Canada, US and France) have the machinery sector in this position, as do Germany, Spain and Australia with the chemical linked group. Differences in sectoral specialisation are also clear with respect to technological transaction balances as almost all sectors appear on both sides of Table 4, with both relatively high and relatively low technology payments/receipts ratios.

Table 3

Domestic R&D capacity in relation to technology imports in manufacturing

		Strongest domestic capacity	Payments/ BERD	Weakest domestic capacity	Payments/ BERD
US	(1986)	Transport equipment	0.001	Machinery group	0.039
Japan	(1987)	Other manufacturing	0.036	Electrical group	0.051
Germany	(1985)	Transport equipment	0.003	Chemical linked group	0.289
France	(1986)	Transport equipment	0.019	Machinery group	0.564
Italy	(1988)	Transport equipment	0.017	Other manufacturing	4.045
Canada	(1986)	Transport equipment	0.075	Machinery group	0.529
Spain	(1986)	Machinery group	0.435	Chemical linked group	1.603
Sweden	(1987)	Transport equipment	0.001	Chemical group	0.063
Australia	(1986)	Transport equipment	0.280	Chemical linked group	0.482

Source: Derived from Appendix 1.

Table 4

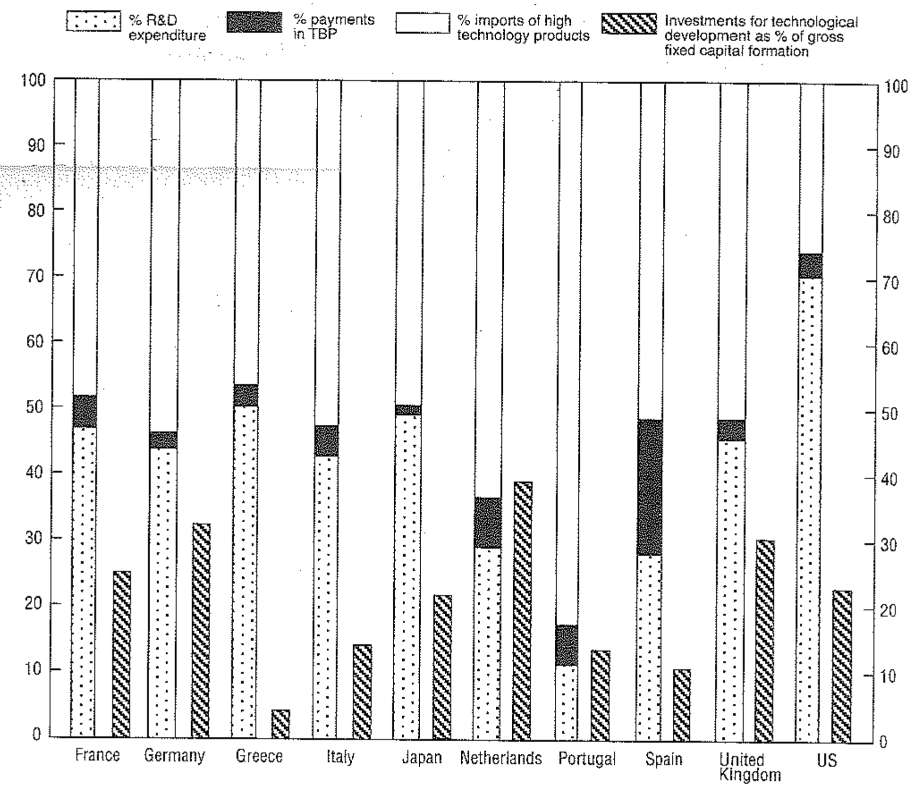
Technology transactions balance in manufacturing

		Best performance	Payments/ receipts	Worst performance	Payments/ receipts
US	(1986)	Chemical linked group	0.025	Machinery group	0.275
Japan	(1987)	Transport equipment	0.991	Machinery group	2.399
Germany	(1985)	Transport equipment	0.115	Basic metal group	4.429
France	(1986)	Chemical linked group	0.767	Electrical group	4.543
Italy	(1988)	Chemical linked group	0.547	Machinery group	5.879
Canada	(1986)	Electrical group	0.625	Chemical group	6.774
Spain	(1986)	Other manufacturing	2.206	Chemical linked group	15.246
Sweden	(1987)	Electrical group	0.079	Other manufacturing	1.000
Australia	(1986)	Machinery group	2.371	Transport equipment	35.500

Source: Derived from Appendix 1.

Figure 1 and Table 5 show the relative shares of the total of gross domestic expenditure on R&D, payments in TBP and imports of high technology products. The data refer to 1985 and 1986 and are all from OECD sources. The situation of the United States clearly differs from the rest. R&D expenditures represent around 70 per cent of total expenditures on these three groups – much more than the others – while imports of high technology products was the smallest, 26 per cent. US payments on TBP are similar to the mean (4 per cent). In Japan bought-in disembodied technology (technology payments) is

Figure 1. **Investments for technological development: 1985**



Source: Sanchez, M.P. (see Note 8).

negligible with only 1.4-1.6 per cent of total expenditures. France, Germany, Greece, Italy and the United Kingdom are very similar to each other, with R&D expenditures around 45 per cent of the total, high-technology imports of the same magnitude and technology payments between 3 and 4 per cent. The difference from the previously used data, where for instance Italy showed a much weaker position, can be partly attributed to the use of total R&D figures. The discrepancy reflects the weight of public expenditure on R&D in relation to company expenditure.

In the Netherlands the high relative weight of both imports of embodied (high technology products) and disembodied technology is remarkable. In Portugal, R&D expenditure is of less importance than in other countries, while

Table 5

Selected investments for technological development

		R&D[a]		TBP Payments[a]		Imports of high technology products[b]		Total
		Value	%	Value	%	Value	%	
France	(1985)	105 914	47.2	9 556	4.3	108 802	48.5	224 272
	(1986)	113 260	50.6	9 486	4.2	101 282	45.2	224 028
Germany	(1985)	49 519	43.1	3 551	3.1	61 722	53.7	114 792
	(1986)	51 870	43.1	4 159	3.5	64 329	53.4	120 358
Greece	(1985)	15 600	50.5	1 124	3.6	14 133	45.8	30 857
	(1986)	18 331	47.9	1 410	3.7	18 489	48.4	38 230
Italy	(1985)	9 132	42.0	1 042	4.8	11 574	53.2	1 748
	(1986)	10 189	44.0	1 056	4.6	11 906	51.4	23 151
Japan	(1985)	8 890	48.2	293	1.6	9 245	50.2	18 428
	(1986)	9 193	49.4	260	1.4	9 172	49.2	18 625
Netherlands	(1985)	8 748	28.6	2 285	7.5	19 509	63.9	30 542
	(1986)	9 533	30.0	2 285[c]	7.2	19 908	62.7	31 726
Portugal	(1985)	11 308[d]	11.2	5 682	5.6	83 671	83.1	100 661
	(1986)	19 868	17.6	5 682[c]	5.0	87 442	77.4	112 992
Spain	(1985)	148	28.6	103	19.9	226	51.5	517
	(1986)	190	32.8	105	18.1	284	49.1	579
United Kingdom	(1985)	8 078	45.0	534	3.0	9 347	52.0	17 959
	(1986)	8 904	45.3	619	3.1	10 154	51.6	19 677
United States	(1985)	110 095	70.5	6 215	4.0	39 799	25.5	156 109
	(1986)	114 705	69.4	7 007	4.2	43 464	26.3	165 176

a) OECD, Gross domestic expenditures on R&D, *Main Science and Technology Indicators*, 1982-88.
b) OECD, *Trade Statistics*, 1974-1986.
c) 1985 data.
d) 1984 data.
Note: Data in millions of national currency. Data for Italy, Japan and Spain in billions of national currency.
Source: Sanchez, M.P. (see Note 8).

the import of high technology products has greater importance. Spain presents a very different picture, showing low R&D effort and a fairly high level of technology payments. These payments, together with the import of high technology products, permit a relatively high technological level of domestic production, which has a positive effect on increasing Spanish exports of high technology products[9]. Technological protectionism is thus counterproductive, but the R&D position is still very weak and technological policy will have to continue to encourage the domestic research effort.

IV. THE SPANISH CASE: A MORE DETAILED ANALYSIS

Spain relies heavily on bought-in technology and a more detailed analysis therefore seems appropriate to determine more precisely the relationship between foreign and domestic technological activities. As more disaggregated data are available for Spain, more detailed analysis on the concentration of payments, receipts and R&D expenditure and the way they complement or substitute each other can be made. Moreover, the use of detailed information provided by the National Institute of Statistics has enabled us to identify the contribution to total payments and receipts of firms undertaking R&D activities. Finally, the size distribution at a sectoral level allows an initial study of the different strategies used by firms of different size.

One of the most striking characteristics of the sectoral breakdown – 63 sectors are studied – is the high level of concentration of both R&D and foreign technological transactions in a small number of sectors. Table 6 shows the first five positions for each of the variables. The percentage columns show the respective concentration ratios (CR). The first three sectors (CR3) represent around 40 per cent of national receipts and BERD, and over 50 per cent of technology payments. The high level of concentration is maintained for CR5

Table 6

Spanish sectoral concentration of technology expenditures, 1986

Percentage

Payments		Receipts		BERD	
Sector	Share of total	Sector	Share of total	Sector	Share of total
1. Motor vehicles (including parts and accessories)	35.1	Service companies	24.5	Chemical industry	16.7
2. Chemical industry	9.8	Building & construction	9.3	Motor vehicles (including parts and accessories)	11.7
3. Service companies	7.8	Instrument engineering	5.6	Other transport equipment	10.9
CR3	52.7		39.4		39.3
4. Office machinery and data processing machinery	7.5	Electrical engineering	5.0	Electronic equipment	9.9
5. Electronic equipment	3.2	Chemical Industry	4.3	Service companies	6.1
CR5	63.4		48.7		55.3
CR10	78.3		66.2		77.3

Source: Data from National Institute of Statistics and Foreign Transactions Directorate, Spain.

and CR10, with only the order of variables changing slightly. The CR10 shows a high level of concentration of all technological activities, thus lending support to those who call for a discriminating, sector-specific policy approach. This argument is also backed up by the similarity among sectors with highest rankings. Sectors with high BERD are often sectors with high payments (four cases), while on the contrary, sectors with high receipts appear to have a weaker relation with the other two variables.

However, the high degree of concentration of technological activities in a few sectors does not mean that a strong correlation between these activities can be inferred for the whole economy. In the Spanish manufacturing sector, which comprises most technological activities, the strongest relationship is between payments and BERD (correlation coefficient 0.62) suggesting a certain degree of balance between these two ways of achieving technological change (Table 7). Surprisingly, domestic R&D and technological exports show a weaker relation (correlation coefficient 0.35) and this poses an interesting question about the origin of the exported knowledge. Questioning increases when looking at the even weaker correlation (0.13) between technological exports and the alternative channel for technological change: technological imports.

Table 7

Correlations between technological activities of Spanish industry, 1986

	Receipts	BERD
Payments	0.13	0.62
Receipts	–	0.35

Source: Author's calculations.

The large range of sectoral differences appears once again when considering the coefficients of technological payments/receipts and payments/BERD. As Figure 2 shows, there are many different sectoral situations, with some very clear outliers deviating from the industry mean. The relative sectoral deficit is especially marked in the nuclear fuel industry, production and preliminary processing of metals, and motor vehicles. The two last cases require an in-depth analysis before detailed conclusions can be drawn, as the technologies involved in these activities are quite mature. For this analysis structural and competitive factors such as firm size and foreign capital penetration need to be taken into consideration.

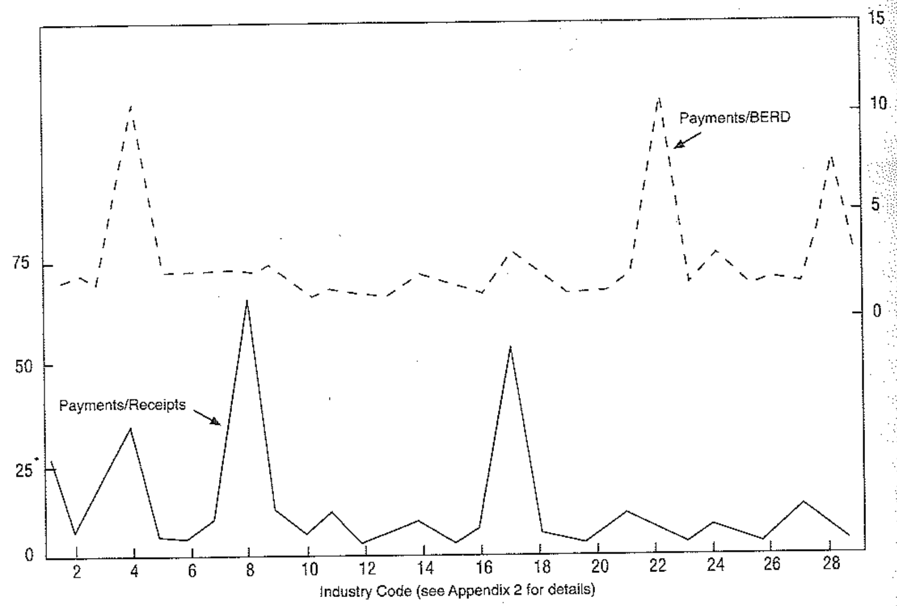
The same applies to the relative strength of domestic R&D and technology imports in some sectors. As extreme cases of net technology importers with very weak domestic BERD, there are two traditional activities – textile and other manufacturing industries – together with the nuclear fuel industry. Once again the factors determining these results lie in the market structure and the economic behaviour of the firms involved. For example, the two traditional industries show a very large dispersion with respect to firm size, reflecting a long protectionist period. There are a few very large companies with either foreign capital or technological links and a large number of small ones with hardly any kind of technological expenditure. On the opposite side is the "other transport equipment sector". It shows intensive R&D activities and very low foreign technology payments. This situation is due to public intervention since the 1960s in the two main activities included in this group: shipbuilding and aircraft manufacturing. Public aid has contributed to generating a fairly high domestic technological capacity.

The sectoral distribution of the two coefficients shown in Figure 2 allows us to infer some similarities but also some discrepancies between activities. They also reveal a complex set of situations and strategies which requires a more detailed and disaggregated treatment, almost on a case by case basis. The clearest similarity appears between nuclear fuel and motor vehicles. They both have a high deficit in their technological transactions and a weak R&D effort compared to their technological payments.

Table 8 shows the different sectoral patterns in the same way as in Table 2 by classifying each activity according to technology payment/BERD and payment/receipt coefficients. Once again group A is formed by those activities with a better domestic technological position in relative terms, a lower technological payments deficit and stronger domestic R&D. It includes very dynamic sectors, at international standard, together with more traditional ones. Examples of the former are electrical engineering and electronic equipment. Group D represents the opposite case, with the technologically weakest sectors. Apart from motor vehicles and nuclear fuel, a great variety of other activities may also be found there, such us food and textile industries, and office machinery and data processing. Finally, groups B and C, as intermediate cases, are characterised by the good performance of one of the two coefficients.

Once the complex set of sectoral situations is considered, a further step can be taken to analyse the different strategic approaches within each sector. The hypothesis is very simple: diverse combinations of foreign transactions and

Figure 2. **International technological transactions and business expenditures on R&D by industry: Spain 1986**



Source: Appendix 2.

Table 8

Sectoral grouping by domestic R&D and foreign technology transactions, 1986

	Payment/BERD < $\bar{y}$	Payment/BERD > $\bar{y}$
Payments/receipts < $\bar{x}$	10, 12, 13, 15, 16, 19, 20, 23, 25, 29 A	2, 5, 6, 18, 26, 28 B
Payments/receipts > $\bar{x}$	1, 3, 11, 27 C	4, 7, 8, 9, 14, 17 21, 22, 24 D

$\bar{x}$: Payments/BERD industry weighted mean. $\bar{y}$: Payments/BERD industry weighted mean.
Source: Derived from Appendix 2. Sectoral numbering as in Appendix 2.

domestic activities are feasible at all levels. This diversity of behaviour can be found within a given sector, where coexisting firms apply different technological strategies.

The impacts of size differences between firms can be analysed with data from the National Institute of Statistics (INE) and the Industrial and Technological Development Centre (CDTI). Table 9 shows the share of R&D-performing firms and R&D expenditure undertaken by units with both research and technological imports. The share of firms combining both increases steadily with firm size, rising from 12 per cent in firms with fewer than 25 employees to 84 per cent in those with more than 1 000 employees. The share of total R&D carried out by these firms also increases according to their size and is always larger than the share of firms, indicating greater R&D expenditure per unit.

Table 9

Spanish firms with R&D and technology imports, 1986

Employment	Firms with R&D activities		Firms with R&D and technology imports			
	Number	Expenditure (m. Ptas)	Number	Percentage of firms with R&D	R&D expenditure (m. Ptas)	Percentage of total R&D
0– 24	210	5 065.3	25	11.9	919.7	18.2
25– 49	110	4 782.6	25	22.7	1 791.0	37.4
50– 99	131	4 853.0	40	30.5	1 734.7	35.7
100–249	202	9 997.4	74	36.6	5 410.2	54.1
250–499	156	13 053.9	94	60.2	10 339.3	79.2
500–999	93	11 826.2	66	71.0	10 107.2	85.5
> 1 000	119	60 759.8	100	84.0	54 755.6	90.1
Total	1 021	110 338.2	424	41.5	85 057.8	77.1

Source: Data from National Institute of Statistics, Spain.

This trend is quite consistent at sectoral level, as Table 10 shows. Applying statistical tests to compare the mean of the different groups, the results obtained confirm the hypothesis of a higher percentage of firms undertaking R&D and technological imports as firm size increases[10]. The differences are significant at 95 per cent or 90 per cent in most cases, the sole exception being 0-49 employees/50-99 employees and 100-499 employees/ >500 employees, which can be interpreted as a delimitation problem.

Table 10

R&D activities of technology importing firms, Spain 1986

Percentage of total R&D undertaken by firms with technology imports

Sector	Employment			
	0–49	50–99	100–499	> 500
Agriculture	42.2	100.0	100.0	0.0
Mining	71.8	100.0	60.6	100.0
Electrical group	15.2	35.3	70.0	97.6
Chemical group	39.3	35.4	78.9	90.4
Transport	35.5	0.8	85.0	97.3
Basic metal group	20.3	81.4	43.6	58.3
Machinery group	12.8	27.5	54.7	44.7
Chemical linked group	28.0	28.7	45.3	96.4
Other manufacturing	80.3	15.5	58.5	99.1
Services (includes utilities and construction)	27.2	45.7	77.8	91.1

Source: Data from National Institute of Statistics, Spain. See sectoral coverage in Appendix 1.

Finally, information on the aims of R&D – the proportion of R&D going to create new technology compared with the proportion to assimilate technology from outside the firm – is presented in Tables 11 and 12. The data come from a survey by the CDTI of firms that do research on a regular basis, and provide information difficult to obtain from the usual statistics. However the results, unlike those in Tables 6 to 10, cannot be applied to all Spanish firms. Once again the analysis takes into consideration the size of firms by number of employees[11]. The conclusions that can be drawn are:

- The number of firms that import technology increases proportionally with size. 85 per cent of the biggest ones make payments abroad while only 16 or 20 per cent of the two smallest groups do so.
- Smaller firms show a higher R&D intensity, in terms of the percentage of their turnover devoted to R&D.
- Smaller firms also show a greater tendency to devote more R&D expenditures to develop new technology than to assimilate outside technology.
- Firms without payments are more R&D intensive which suggests a certain concentration in their technology strategies. But in all groups there are some firms without payments that devote part of their R&D effort to assimilating imported technology. This is probably because they are acquiring embodied technology and they invest in assimilating and adapting it.

- As expected, firms without payments tend to develop new technology more than the others. The firms that import disembodied technology devote a higher percentage of R&D to assimilate it. This is true for all groups except firms with more than 500 employees, but in this group, only 3 companies out of 20 do not import technology, making the sample too small to be significant.

Table 11

Technology activities in Spanish firms, 1986

Employment	Number of firms (A)	(%)	Number of firms with TBP payments (B)	B/A (%)	R&D (percentage of turnover)				R&D for technology creation (C) versus adaptation (A)				
					< 1	1–10	> 10	n.a.	100% (C)	< 50% (A)	> 50% (A)	100% (A)	n.a.
< 50	45	35.2	9	20	1	15	20	9	18	10	10	5	2
50–250	36	28.1	6	16	6	25	4	1	12	13	6	3	2
251–500	27	21.1	8	30	6	19	1	1	15	7	4	0	1
> 500	20	15.6	17	85	9	9	2	0	4	7	6	1	2
Total	128	100	40	31.3									

n.a. = Not available.
Source: Industrial and Technological Development Centre (CDTI).

Table 12. **Technology activities in Spanish firms, 1986**

Employment	Firms with payments in TBP									Firms without payments in TBP								
	R&D intensity[1]				R&D for technology creation (C) versus adaptation (A)					R&D intensity				Creation (C) versus adaptation (A) of technology				
	< 1%	1–10%	> 10%	n.a.	100% (C)	< 50% (A)	> 50% (A)	100% (A)	n.a.	< 1%	1–10%	> 10%	n.a.	100%	< 50% (C)	> 50% (A)	100% (A)	n.a. (A)
< 50	1	2	3	3	1	4	3	1	0	0	13	17	6	17	6	7	4	2
50–250	1	5	0	0	0	4	1	1	0	5	20	4	1	12	9	5	2	2
251–500	2	6	0	0	3	4	1	0	0	4	13	1	1	12	3	3	0	1
> 500	8	7	2	0	4	6	5	1	1	8	7	2	0	4	6	5	1	1

n.a. = Not available.
1. Percentage of turnover devoted to R&D.
Source: CDTI.

V. CONCLUSIONS

All countries use both domestic R&D and foreign technological transactions to achieve technological change. However, there are clear differences between their use of each that reflect their domestic technological capacity. These differences also apply at a sectoral level within particular countries, suggesting diverse patterns of technological specialisation and capacities.

The analysis for Spain shows a very unbalanced situation between R&D activities and imports of disembodied technology. As in other countries there is a high degree of concentration of technological activities in a few companies and sectors. However, there is no solid evidence to infer the existence of complementary R&D and technology import activities at firm level in all sectors. Firm technological activities and strategies in every major sector would need a more in-depth study to establish the pattern of technological activities.

The situation described for Spain may also apply to other small or less developed countries. In such cases, although diffusion policy measures have to be implemented, business R&D should also be encouraged. Nevertheless scientific and technological policy must take note of the sectoral diversity and strategic differences of the firms involved.

An effort should be made to improve technological indicators in order to allow national analysis and international comparisons.

Three policy considerations appear particularly important:

a) The need for a balance between domestic R&D and import of foreign technology. While some countries may be reluctant to consider such a balance as an objective, others have underlined its existence, notably in more developed countries. However, this balance may not be an objective by itself but the result of scientific and technological policy actions;

b) The characteristics of imported technology should be taken into consideration when defining R&D priorities. Although this is not often put into practice, the approach has been widely canvassed. There is a growing consensus that R&D performance is a *sine qua non* condition for the efficient use of foreign technology;

c) The different perception of the desirable balance between domestic/imported technology in small and large countries. Although the size of the country may not be the most important factor, the size of the market that a particular economy is supplying and the technological level achieved are considered important determinants of this balance.

Appendix 1

Technology payments/Receipts

	US (1986)	Japan (1987)	Germany (1985)	France (1986)	Italy (1988)	Canada (1986)	Spain (1984)	Sweden (1987)	Australia (1986)
Agriculture	0.000	0.000	0.000	6.559	1.601	0.000	0.877	0.000	0.000
Mining	0.000	0.200	0.000	0.000	3.538	0.000	10.573	0.000	0.000
Electrical group	0.208	1.791	3.652	4.543	2.961	0.625	5.291	0.079	12.763
Chemical group	0.045	1.111	0.967	1.261	3.532	6.774	4.092	0.359	8.597
Transport equipment	0.027	0.991	0.115	0.960	0.677	0.000	8.357	0.857	35.500
Basic metal group	0.059	1.557	4.429	1.119	0.000	0.000	6.214	0.800	11.417
Machinery group	0.075	2.399	1.358	1.453	5.879	1.586	2.433	0.419	2.371
Chemical linked group	0.025	1.275	3.627	0.767	0.547	0.000	15.246	0.462	0.000
Other manufacturing	0.161	1.010	2.000	1.688	5.097	2.179	2.206	1.000	27.500
Services	0.371	0.129	5.800	0.332	3.095	0.835	1.495	0.843	0.670

Technology payments/BERD

	US (1986)	Japan (1987)	Germany (1985)	France (1986)	Italy (1988)	Canada (1986)	Spain (1984)	Sweden (1987)	Australia (1986)
Electrical group	0.005	0.051	0.120	0.054	0.102	0.177	1.071	0.007	0.282
Chemical group	0.006	0.038	0.087	0.168	0.201	0.368	0.843	0.063	0.448
Transport equipment	0.001	0.050	0.003	0.019	0.017	0.075	1.236	0.001	0.280
Basic metal group	0.012	0.049	0.037	0.210	0.000	0.000	0.763	0.009	0.157
Machinery group	0.039	0.045	0.044	0.564	0.641	0.529	0.435	0.008	0.124
Chemical linked group	0.007	0.042	0.289	0.287	1.282	0.000	1.603	0.022	0.482
Other manufacturing	0.000	0.036	0.066	0.343	4.045	0.430	1.001	0.009	0.375
Services	0.088	0.044	0.081	0.143	0.210	0.218	1.265	0.016	0.233

Notes: **US:** Mining is included in Services.
Japan: Agriculture not disclosed for confidential reasons; Electrical group includes office machinery and computer; Utilities are included in other manufacturing group.
Germany: Electrical group includes office machinery and computer; Textiles and Clothing are included in other manufacturing group.
France: Mining is included in chemical group.
Italy: Mining includes petroleum refineries, ferrous metals, non-ferrous metals and stone, clay and glass.
Canada: Chemical group includes chemical linked group; Services include agriculture and mining.
Sweden: Rubber and plastic is included in chemical group; Services include agriculture.
Australia: Services include mining.

Source: Author's calculations.

Appendix 2

Technology payments receipts and BERD by industry: Spain 1986

Million Pesetas

Sector	Payments	Receipts	BERD	Payments/ BERD	Payments/ Receipts
1. Extraction and briquetting of solid fuel coke ovens	195.4	6.5	1 368.5	0.14	30.29
2. Extraction of petroleum and natural gas	406.5	468.5	310.2	1.31	0.87
3. Mineral oil refining	1 267.0	88.9	1 901.4	0.67	14.25
4. Nuclear fuel industry	888.2	25.2	81.0	10.97	35.25
5. Electricity, gas, steam and hot water	2 619.6	723.0	2 412.4	1.09	3.62
6. Water supply	79.2	40.7	69.0	1.15	1.95
7. Extraction and preparation of metalliferous ores	627.2	76.5	457.7	1.37	8.20
8. Production and preliminary processing of metals	3 419.0	47.7	2 324.2	1.47	71.63
9. Extraction of other minerals	211.5	25.5	119.3	1.77	8.29
10. Manufacture of non-metallic mineral products	536.9	151.9	2 212.7	0.24	3.53
11. Chemical industry	10 206.0	1 071.1	18 399.3	0.55	9.53
12. Manufacture of metal articles	1 307.2	1 053.8	3 148.0	0.42	1.24
13. Mechanical engineering	2 220.3	763.1	5 731.2	0.39	2.91
14. Manufacture of office machinery and data processing	7 794.1	943.6	5 696.2	1.37	8.26
15. Electrical engineering	3 323.6	1 251.8	5 004.4	0.66	2.66
16. Electronic equipment	3 441.4	760.4	10 901.3	0.32	4.53
17. Motor vehicles (included parts)	32 760.6	556.0	12 883.5	2.54	58.93
18. Shipbuilding	880.3	242.5	678.2	1.19	3.33
19. Other means of transport	982.1	839.7	11 995.1	0.08	1.17
20. Instrument engineering	318.8	1 405.8	618.1	0.52	0.23
21. Food, drink and tobacco	4 379.8	480.4	3 827.5	1.14	9.12
22. Textile industry	1 170.4	189.7	100.1	11.69	6.17
23. Leather and leather goods	66.3	31.3	134.3	0.49	2.12
24. Footwear and clothing	563.0	98.8	206.7	2.73	5.70
25. Wood and furniture industry	79.3	39.1	97.7	0.81	2.03
26. Paper, printing and publishing	639.4	565.8	694.6	0.92	1.13
27. Rubber and plastics	3 248.5	276.0	3 723.7	0.87	11.77
28. Other manufacturing industries	2 225.2	694.2	280.7	7.93	3.21
29. Building and civil engineering	1 083.3	2 311.5	1 510.8	0.72	0.47

Source: Data from National Institute of Statistics and Foreign Transactions Directorate.

NOTES AND REFERENCES

1. OECD (1988), *Science and Technology Policy Outlook*, Paris.

2. "Diffusion" is used in a broad sense meaning the adoption of technology produced elsewhere. It includes both embodied and disembodied technology and the diffusion within the frontiers of a country and between countries. We devote special attention to this latter case which is often referred to in the literature as technology transfer from abroad.

3. See Soete, L. *et al.* (1991), "Recent comparative trends in technology indicators in the OECD area", *Technology and Productivity – The Challenge for Economic Policy*, OECD, Paris.

4. Grupp, H. (1991), "Innovation dynamics in OECD Countries: Towards a correlated network of R&D intensity. Trade, patent and technometric indicators", *Technology and Productivity – The Challenge for Economic Policy*, OECD, Paris.

5. According to the Technological Balance of Payments Manual these flows cover the financing of R&D performed outside the country. Payments from a given country A represent the R&D financed by residents of A and performed elsewhere. Receipts in A represent the R&D performed in A and financed by non-residents. The work must be industrial and technological R&D. They include funds provided for R&D purposes between related or unrelated companies. The financing of scientific R&D such as co-operation in science or contributions to intergovernmental research bodies should not be included. However, some borderline cases such as R&D carried out jointly by private companies and university laboratories or European Community programmes have to be taken into consideration. See OECD (1989), *The measurement of scientific and technological activities. Proposed standard method of compiling and interpreting Technology Balance of Payments data*, Paris.

6. Because of their length they are not given in this paper, but they can be made available on request to the authors.

7. Antonelli, C. (1982), "Technology payments and economic performance of Italian manufacturing industry", OECD, unpublished paper.

8. Sanchez, M.P. (1989), "El desafío tecnológico para la empresa española de los 90", in: *La economía española en el mercado interior en 1993*, Pirámide, Madrid.

9. Sanchez, M.P. (1988), "Technology exports by Spanish companies", *STI Review, No. 4*, pp. 167-189.

10. **Statistical results: comparison of group size**

0–49	50–99	100–499	> 500
0–49	DF = 16 t = 0.74[a]	DF = 17 t = 3.29[b]	DF = 16 t = 3.14[b]
50–99		DF = 14 t = 1.64[c]	DF = 18 t = 2.00[b]
100–499			DF = 14 t = 0.84[a]
> 500			

DF : Degrees of freedom approximated using Brownley, K.A. (1965), *Statistical Theory and Methodology in Science and Engineering*, Wiley and Sons, New York. For the case that population variances are not assumed to be equal.

a) Not significant.

b) t value significant at 95%.

c) t value significant at 90%.

11. The criteria of the number of employees is, in our opinion, the least adequate of all size criteria for technological comparison purposes since it is likely to be influenced by the technological level of the firm. However, it was the only size measurement available.