TECHNICAL CHANGE AND INCORPORATED R&D IN THE SERVICE SECTOR*

Bruno Amable[a] (INRA and CEPREMAP, Paris, France)

Stefano Palombarini (CREA and CEPREMAP, Paris, France)

Abstract

The purpose of this article is to study the pattern of technical change in the service sector using an indicator of total technology intensity which takes account of the R&D incorporated in purchases of intermediates and equipment. The service sector does not appear as homogeneous and some services are major users of technology. An international comparison over 8 countries does not show a clear pattern of convergence in total technology intensity except for the communication services. A comparison between France and Germany emphasises the differences between the relative importance of domestic and imported incorporated technology.

Keywords: Services, R&D intensity, incorporated technology, Input-output Tables

Changement technique et RD incorporée dans le secteur des services

Résumé

Le but de cet article est d'étudier le mode de changement technique dans le secteur des services en utilisant un indicateur d'intensité technologique totale qui prend en compte les dépenses de recherche-développement incorporées dans les équipements et biens intermédiaires achetés par le secteur tertiaire. Le secteur des services n'apparaît pas homogène et certains services sont de grands utilisateurs de technologie. Une comparaison internationale portant sur 8 pays ne fait pas apparaître clairement un mouvement de convergence dans les valeurs des intensités technologiques totales, sauf pour le secteur de la communication. Une comparaison France-Allemagne souligne les différence des parts relatives de la technologie incorporée domestique et de la technologie incorporée importée.

Mots-clés : Services, intensité R&D, technologie incorporée, tableaux input/output.

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[a] Corresponding author. CEPREMAP 142 rue du Chevaleret, 75013 Paris, France. E-mail: bruno.amable@cepremap.cnrs.fr.

I. Introduction

The continuous increase in the share of the service sector in the economy for at least the past thirty years is one of the most striking facts characterising the economic evolution of developed countries. The growing importance of this sector has paralleled the slowing down of productivity growth in OECD countries, and the argument linking the two phenomena is well known.[1] A structural change favouring the rise of service activities is supposed to have detrimental effects on the growth of productivity in the whole economy since it is believed that service activities either experience little if any productivity growth or are at best able to produce localised, non transferable innovations, whereas industry produces innovation which diffuse throughout the whole economy. The precise assessment of productivity and its evolution in the tertiary sector is a well-known complex issue because measurement is more difficult in services than in manufacturing. However, it is difficult to maintain that there is no productivity growth at all in these activities.[2] Besides, services are a major contributor to manufacturing sectors as established recently for the UK by Tomlinson [1997]. The vision of an isolated manufacturing sector as a superior, productivity-leading branch of the economy is obsolete.

It is now widely acknowledged that there is innovation in services, which takes forms that are to some extent different from the forms of innovation in industry.[3] The service sector is often considered as a supplier-dominated activity, following the classification of Pavitt [1984], which implies that innovation in services is supposed to be of the capital-deepening and labour-saving process type. This view is somewhat restrictive[4] since some service activities are characterised by a high capital intensity and it is highly unlikely that services do not play a role in the shaping of technologies they are using ; one must not forget either the important non technological innovative effort in many services such as communication or finance. But the process innovation supplier-dominance view is however considered as generally correct for many services.

Barras ([1986] and [1990]) has proposed a model of reverse product cycle for service innovation which goes beyond the mere consideration of the diffusion of equipment. Contrary to the traditional industrial cycle wherein product innovations come first, the reverse product cycle is characterised by the fact that process innovations, incremental as well as radical, are followed by product innovations. In the first phase, new technologies transform parts of the services' production process and may imply a lowering in quality of some services, offset by an improvement in delivery.[5] In the second phase, there is product innovation, involving the creation or improvement of high quality services, with the use of new process technology. Information and Communication Technologies (ICTs) play an important role in this innovation process. The fact that services are major users of ICTs, which the most

[1] at least since Baumol [1967].
[2] Communication services were estimated by OECD [1996] to be the activity with the highest total factor productivity growth in France and the third highest in the US between 1972 and 1990.
[3] A key reference is Barras [1986]. Callon, Larédo and Rabeharisoa [1997] emphasise the specificities of innovation in the service sector. Gallouj and Weinstein [1997] propose some foundations for the theory of innovation in services.
[4] See Hauknes and Miles [1996].
[5] Petit and Soete [1996].

important technological changes of the past 20 years have been associated to, is another indication of the technological dynamism of the service sector.

The reverse product cycle theory emphasises the importance of the diffusion of new processes in the technological trajectory of services. Of course, innovation in services does not only possess one point of entry,[6] the technical characteristics of the production process, but one may still expect that the diffusion of new equipment should be an important matter for technological improvement in the services. In an important way, service innovation is connected to the diffusion of innovation equipment.

The classification of manufacturing activities with respect to technology is often based on technology intensity, i.e. the ratio of R&D expenditures in a given industry to production or value added of that industry. According to this criterion, service activities possess a very low technology intensity since almost no R&D expenditures are usually reported for them.[7] Another way to estimate the technology content of an activity is to use not only the direct R&D expenditures related to a particular sector, but also the indirect expenditures such as those incorporated in equipment and intermediates. This may be particularly relevant for the service sector since in many cases, innovation is organised in a different way from the industry. There may exist an organised innovation process in many service activities without necessarily the existence of specialised research departments.[8] Therefore, the consideration of direct R&D expenditures only would underestimate innovation and technical progress in general.

The computation of 'incorporated' R&D can be made with the help of input/output tables, and R&D inputs can be allocated to the end-destination of the products they enter in. Such an exercise applied to manufacturing industries has led to a reappraisal of the classification of industries as high, middle or low tech (OECD [1996]).

The purpose of this article is to apply the same methodology to the service sector, breaking down the whole tertiary sector into five sub-sectors,[9] and to show that services are more technologically sophisticated than what is usually thought.[10] The computation of the total R&D intensities allows to have a more precise idea on the pattern of technology diffusion within the service sector. Section II below describes the method, and applies it to service activities in 8 OECD countries. The evolution of the R&D intensity of service sectors is analysed in section III. The next section distinguishes between foreign and domestic sources of R&D, i.e. the sources of intermediates and equipment incorporating R&D, in order to shed some light on the question of a possible link between a strong component of domestic R&D and a

[6] Gallouj and Weinstein [1997].

[7] Some countries have data on R&D expenditures of the service sector, but unfortunately, at the time of writing this article, there is no complete internationally comparable and reliable data on services R&D that could be used in the present study. Some data for certain service sectors and certain countries are available from the OECD (see also Young [1996]), but it was not possible to add these direct R&D expenditures to the indirect, incorporated R&D considered in the paper.

[8] See Callon, Larédo and Rabeharisoa [1997].

[9] As argued in Gallouj and Gallouj [1996] in order to analyse technological trajectories in services, it is necessary to disaggregate so heterogeneous a sector.

[10] See Hauknes and Miles [1996] for a similar point.

high R&D intensity in the services, i.e. the question of imperfect substitutability between foreign and domestic incorporated R&D. Following on this matter, the last section proposes a comparison between France and Germany, particularly with respect to the origins of R&D used in the financial, governmental and social services.

II. Incorporated R&D and the service sector

It is widely recognised that R&D expenditures offer a highly biased evaluation of innovative efforts. The *Frascati Manual* deliberately excludes from R&D a whole range of activities that are of primary importance to account for the dynamics of innovation and technological change in the service sector: feasibility studies or policy evaluation studies for instance. Although not strictly research or development, such activities are instrumental in identifying the specific needs that service activities could satisfy and hence matter a great deal for the innovative strategies of service firms. Likewise, education and training, marketing studies, normalisation studies,... are too excluded from R&D. However, the definition of R&D in the Frascati Manual has improved and now includes expenditures related to new software development, but not software implementation : support to existing systems, conversion or translation of programming languages, addition of new functions to existing programs,... all of these are explicitly excluded from R&D measures because no significant scientific or technological improvement is involved. Yet, making a clear difference between the two types of software-related activities may turn out to be difficult and may lead to arbitrary definitions of research in service activity.

As acknowledged in the *Oslo Manual*, the accounting of R&D expenditures is highly influenced by the so-called linear model of innovation, where research is followed by an invention which later gives a marketable innovation. This assumed linearity has 'naturally' selected R&D expenditures as one of the most fundamental innovative indicators since it lies at the source of the innovative process. However, the linear model has been met with an increasing amount of criticism over the past decade. The emphasis that this representation puts on a succession of isolated stages does not fit well with the perception of innovation that has come to the foreground more recently : innovation does not come solely out of the research laboratories and technical change is not limited to the discovery of new scientific principles. Activities ruled out as R&D play an important role in services innovation or research. A service firm may for instance define new products and processes through interactions with customers, leading to the customisation of services. As stressed in the Maastricht memorandum[11], there are multi-directional linkages between the different phases of the process of technical change. This matters particularly for services where the co-production relationship between client and producer, i.e. the involvement of the client in the definition of the identity of the product, is widespread. This may lead to the definition of *ad hoc* innovations, linked to the specific characteristics of the client and the producer.[12]

Moreover, the importance of the contribution of services to manufacturing seems to indicate that the alternative to the linear model of technological change

[11] Soete and Arundel [1993] .
[12] Gallouj and Gallouj [1996].

may not be so much the interactive model[13] than a new mode of organisation of production, with a weakening of functional frontiers between services and manufacturing. To some extent, the rise in the GDP share of services indicates not only structural change within most economies, but also a growing inadequacy of the traditional national accounting apparatus. Therefore, a larger share of service in the economy does not imply a rise of activities with slow productivity gains.

From a traditional 'linear' point of view, the service sector appears as a poor innovator indeed. Until recently, no R&D expenditures were credited to these activities in most databases. OECD figures on R&D in services[14] make international comparisons difficult because the reliability of the data seems to vary considerably across countries. For instance, services' R&D expenditures seem to be underestimated for Japan or Germany since the figures reported in Young amount respectively to 2.3 and 2.4 % of aggregate Business Enterprise R&D (BERD) only. Such figures appear too low to be trusted, and this is confirmed by the fact that R&D surveys coverage is considered as too low in these (and other) countries. On the other hand some countries have a good R&D survey coverage for service activities and appear as high R&D spenders (USA, UK, Canada,...), with services representing over 10% of BERD, and values of ratios of services BERD over value added ranging up to 1% (USA).

In any case, considering services as low technology activities would not fit too well with a few facts:

- the skill level of the work force employed in some services is rather high[15] and the growing share of the service sector in GDP has paralleled the decrease in low skilled jobs for most OECD countries ;
- the service sector is a large user of R&D intensive goods such as IT

On this last topic, it may be interesting to assess more precisely the technological content of service activities, and compare it with agriculture or manufacturing. Considering that new technology is largely incorporated in new equipment goods, either produced domestically or imported, one way to trace the diffusion of innovation throughout the various activities in the economy is to use input/output matrices and to try to define a measure of indirect R&D, i.e. a measure of R&D expenditures incorporated in equipment or intermediates. This way, R&D expenditures in one sector are attributed to all sectors proportionately to the intra- and inter-industry flows. It is a way to measure the equipment embodied diffusion of technological change, through the purchase of inputs that incorporate new technology, measured with the help of R&D expenditures. This method is presented in OECD [1996][16] and the statistics presented in this paper use the same input-output tables.

[13] Kline and Rosenberg [1986].
[14] See Young [1996].
[15] Service employment seems to be characterised by dualism. Some activities, such as production of software, could be considered as quasi-R&D whereas other more traditional services rely on a poorly skilled workforce.
[16] See also Sakurai, Papaconstantinou and Wyckoff [1996].

To consider a broad service sector is too rudimentary to have an assessment of the innovative capacity of service activities. First, as mentioned earlier, the classification of activities into three sectors (primary, secondary, tertiary) is partly obsolete since structural change and technical progress tend to blur the distinction between industry and services. Second, one would want to have a deeper look into the service sector since such a large area of economic activity is likely to encompass activities which are very different from each other with respect to the effect of technological change and innovation.

OECD statistics allow to distinguish five sub-sectors within the service sector, which define five broad types of activities:

A Transportation services
B Communication services
C Financial services
D1 Trade and hotels
D2 Social and governmental services

The disaggregation adopted here is not founded on the various taxonomies found in the literature[17] but on statistical categories on which the statistics are based. The adoption of a technology-based taxonomy would have been useful for an analysis of innovation in services, but we are more concerned with the incorporation of technology than, for instance, product innovation. Besides, data availability prevents us from adopting another disaggregation.

As mentioned before, the direct R&D intensity in services from OECD databases are not easy to incorporate into our study. When one considers indirect R&D travelling between sectors through intermediate products and investment inputs, one obtains the figures in Table 1a. Data for the most recent year (1990) are shown here, the evolution of the indirect R&D coefficients will be addressed in the next section.

The incorporation of indirect R&D changes the picture quite drastically. Comparing the three broad sectors (agriculture, industry, services), one notices that the total R&D intensity of the service sector is superior to that of agriculture in some countries (Canada, UK and the USA). Communication, transportation and social services possess a higher R&D intensity than agriculture. But more significant is the fact that communication services exhibit in most countries a total R&D intensity which is in the range of 1.5 to 2%, i.e. in the same range as industries such as fabricated metals, all this on the strength of R&D incorporated in intermediate and equipment goods only. Overlooking R&D performed by services implies of course an underestimation of total R&D intensities. This factor is all the more important that intersectoral technology flows seem to be high within the service sector.[18]

[17] For instance Soete and Miozzo [1990]. See Gallouj and Gallouj [1996] for a discussion of these taxonomies.
[18] See OECD [1996].

Table 1a. total R&D intensity in 1990*

	Canada	**Denmark**	**France**	**Germany**
Transportation services	0.76%	0.60%	1.12%	1.41%
Communication services	2.08%	0.30%	1.36%	1.50%
Financial services	0.13%	0.10%	0.38%	0.39%
Trade and hotels	0.15%	0.17%	0.23%	0.41%
Governmental and social services	0.56%	0.36%	0.79%	0.81%
Total industry	0.82%	0.82%	1.38%	1.73%
Primary sector	0.23%	0.61%	0.48%	1.06%
Manufacturing sector	1.81%	2.10%	3.22%	3.24%
Private services sector	0.38%	0.28%	0.44%	0.63%
	Japan	**Netherlands**	**UK**	**USA**
Transportation services	1.38%	0.78%	0.51%	1.26%
Communication services	1.50%	0.66%	1.69%	1.60%
Financial services	0.71%	0.14%	0.57%	0.42%
Trade and hotels	0.85%	0.23%	0.39%	0.45%
Governmental and social services	*(D1=D1+D2)	0.47%	0.50%	0.74%
Total industry	1.97%	1.25%	1.32%	1.72%
Primary sector	0.92%	0.45%	0.45%	0.50%
Manufacturing sector	3.62%	2.88%	3.23%	4.18%
Private services sector	0.91%	0.37%	0.55%	0.63%

* except for the Netherlands (1986).

Some doubts might be raised about the ability of production figures taken out of OECD National Accounts to reflect the actual importance of the service sector. A way to overcome this potential problem is to compute the R&D coefficient with respect to employment. However, measuring the R&D content of services this way gives a similar picture. One must note however that using an employment-based indicator raises new problems since two effects are taken into account: the R&D incorporated in services' production and the rise in labour productivity of services. This explains why one must interpret cautiously the findings reported in Table 1.b as much as those from Table 1a. Differences across countries may come from varying capital/labour ratios and rises in the indicator, may be explained by increases in labour productivity. Besides, it was not possible to control for actual working hours in the use of employment statistics, so that distortions in the computation of the indicator were inevitable. Lack of data prevented the computation of the employment-based indicator for the UK and limited it for Japan and Germany: it is not possible to distinguish transportation services from communication services nor trade and hotels from governmental and social services for the former, and financial services are grouped with governmental and social services for the latter.

Comparing the whole service sector with the manufacturing and primary sectors roughly confirms previous findings. Being more capital intensive, the manufacturing sector exhibits a larger difference with the service sector in the value of the R&D/employment coefficient, and for the same reason, the primary sector's figures are generally higher than those of services, with a notable exception for Japan, whose agriculture is known to be much less capital-intensive (and productive) than the agricultural sectors of other developed countries. Within the service activity, differences across countries are sometimes more pronounced than with the production-based indicator. The most striking difference concerns financial services

which sees a low value of the R&D/employment ratio in Denmark contrast with a very high one in Japan. This reflects partly the relative productivity of financial services across countries as well as across service sub-sectors within one country. One should be even more cautious in the interpretation of productivity indicators that could be taken from our data than with the R&D indicators data, but the computations reported in the appendix suggest that financial services in Japan have a productivity level which is about three times as high as average Japanese services productivity. But then again, this is not to be taken as an indicator of international competitiveness of Japanese financial services.

Table 1b. The R&D/employment coefficient in 1990*

	USA	Canada	Japan	Germany	France	Netherlands	Denmark
Transportation services	1.26	0.55	1.15	0.94	0.83	0.42	0.43
Communication services	2.31	0.94	1.15	0.87	0.73	0.34	0.14
Financial services	0.49	0.09	1.42	0.45	0.56	0.10	0.08
Trade and hotels	0.24	0.05	0.37	0.18	0.12	0.09	0.08
Governmental and social services	0.23	0.21	0.37	0.45	0.31	0.18	0.12
primary sector	0.56	0.17	0.20	0.46	0.31	0.42	0.32
manufacturing	6.20	2.12	5.59	3.32	3.84	3.43	1.54
private services sector	0.44	0.16	0.66	0.38	0.27	0.17	0.11

millions of dollars PPP/total employment.
* except for the Netherlands (1986).

If one wants to rank sectors according to R&D intensity, one generally observes that communication services are in most countries the most R&D intensive activity, followed by transportation services, social and governmental services, financial services and finally trade and hotels. Therefore, the classification of the service sector adopted above seems to reflect a differentiated pattern of technology use and incorporation by each sub-sector. These service activities more or less seem to adopt the same pattern of technology use, as measured by the total R&D intensity. Since transportation services may be more capital intensive than communication services in some countries, they may come first when one looks at the R&D-employment indicator, but on the whole, the same results apply.

The United Kingdom, Denmark and the Netherlands exhibit a different ranking, because communication services have a very low total R&D intensity in the latter two countries, and the financial sector has a high intensity in the UK. Denmark and the Netherlands have a weak R&D intensity in all service sectors, and the high R&D intensity of finance related activities in the UK reflect to some extent a particular sectoral specialisation. British transportation services exhibit a very low R&D intensity in comparison to France, Germany, Japan and the US. Of course, all this reflects recent trends only since these comparisons concern 1990. The evolution of the R&D intensities will be addressed in next section. It can be noted here however that the low British R&D intensity for transportation services is recent since, as shown in Figure 1 below, the UK had middle-range values for the R&D/production coefficient until the mid-1980s.

Taking each sector separately, the ranking of countries according to incorporated R&D intensity (Tables 2a and 2b) clearly indicates that the Netherlands and Denmark can be classified as 'low incorporated R&D intensity' countries, and this does not apply to 1990 only. Germany, Japan and the USA, on the other hand are countries where the service sector has a high R&D intensity. The other countries have a degree of R&D intensity which varies according to the sub-sectors considered, which partly reflects the pattern of internal specialisation within the service sector, i.e. the relative share of each service sub-sector. The case of financial services in Canada is special. The figures for the R&D intensity or the R&D-employment ratio is particularly low for 1990, similar to the values for Denmark and the Netherlands. This however is specific to the year 1990, since the general pattern before this date was very similar to that of the other countries. The drop is due to a steep decrease in (mainly imported) equipment investment between 1986 and 1990. By cutting down on imported equipment, and hence on R&D incorporated in this equipment, Canada becomes more similar to the Netherlands and Denmark which are characterised by a relatively low share of imported incorporated R&D in the financial service sector.[19]

Table 2a. Ranking of countries according to R&D intensity by sector

Transportation services	Germany, Japan, USA, France, Netherlands, Canada, Denmark, UK
Communications services	Canada, UK, USA, Germany and Japan, France, Netherlands, Denmark
Financial services	Japan, UK, USA, Germany, France, Netherlands, Canada, Denmark
Trade and hotels	USA, Germany, UK, Netherlands and France, Denmark, Canada
Social and governmental services	Germany, France, USA, Canada, UK, Netherlands, Denmark
Trade and hotels, Social and governmental services	Japan, Germany, USA, France, UK, Canada, Netherlands, Denmark

Table 2b. Ranking of countries according to the R&D/employment ratio

Transportation services	USA, Germany, France, Canada, Netherlands, Denmark
Communications services	USA, Canada, Germany, France, Netherlands, Denmark
Financial services	Japan, France, USA, Netherlands, Canada, Denmark
Trade and hotels	USA, Germany, France, Netherlands, Denmark, Canada
Social and governmental services	France, USA, Canada, UK, Netherlands, Denmark

The dynamism of the service sector as a whole is a function of the structural dynamics within this sector since, as seen above, the sub-sectors are quite different from one another from the point of view of technology incorporation and hence, one may assume, from the innovative point of view. This again points against the representation of the service sector as a whole as one large conglomerate of activities characterised by a low technological level and a moderate use of technology. Countries considered here are quite different from the point of view of the structure of the service sector. On the whole,[20] Japan, Canada and the UK, and to a lesser extent the US, are countries where services that incorporate a relatively high share of R&D have a greater share than in the other countries. If one assimilates these activities to the more dynamic and innovative, one may be led to

[19] See Appendix C for Figures reporting the share of domestic R&D.
[20] See Appendix B for data regarding the relative importance of each service sub-sector.

tone down, for these countries at least, the appreciation that the increasing share of service sectors in the economy are slowing down productivity growth.

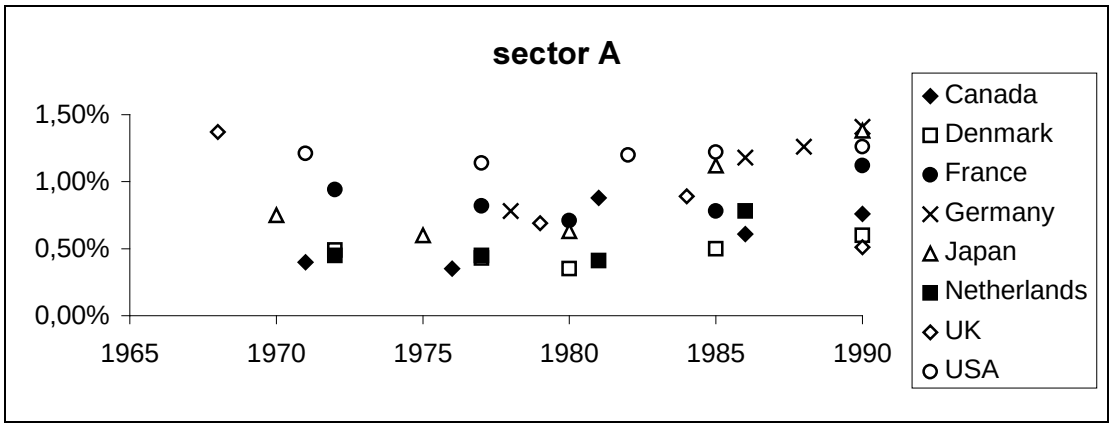
III. The dynamics of R&D intensity

The R&D intensity coefficients which the preceding section discussed reflects the incorporation of advanced equipment and the use of intermediates. The pattern of use of intermediates and equipment by the service sector has changed over time under the influence of structural change, both internal to the service sector and external, as well as technical change. Therefore, the evolution of the R&D coefficients reflects the impact of these changes on the service sector.

Figures 1 to 5 describe the evolution of the R&D intensity coefficients between 1965 and 1990. A first observation is that one there is no general pattern which is common to all activities within the service sector. For communication services, one observes a pattern of convergence towards similar levels of R&D intensity, which could be interpreted as a pattern of homogenising in the use of intermediates and equipment. Communication services are major users of IT, the technologies which have seen their importance growing the most in the past 20 years. The figures show that in most countries,[21] communication services have become increasingly similar in their use of technology incorporating equipment. The IT paradigm can therefore be suspected to be so strong as to impose a parallelism in the technological evolution of these services.

Such a pattern of convergence in the R&D coefficient cannot be found in other service sub-sectors. One roughly observes a general trend towards an increase in the coefficients, with the Netherlands and Denmark always characterised by low values for R&D intensity. One may note that the two countries exhibit almost identical dynamic pattern for the R&D coefficient in all sectors.

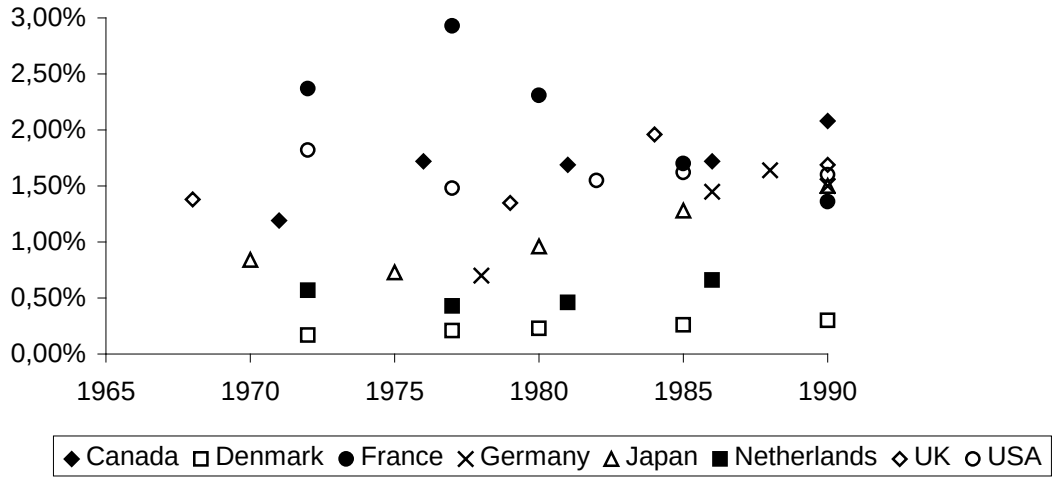
Figure 1. The evolution of R&D intensity in transportation services



[21] Denmark and the Netherlands are again exceptions.

In transportation services, the R&D coefficient stayed more or less constant or even decreased until the 1980s and then increased in all countries, with no tendency to homogenisation across countries. The hierarchy of countries evolved a little over the period considered: The German and Japanese coefficients increased the most, French and British coefficients followed a U-shaped pattern, while the US R&D ratio stayed more or less constant.

Figure 2. The evolution of R&D intensity in communication services



As mentioned before, the communication sector is characterised by a convergence in the R&D coefficient for all countries except Denmark and the Netherlands, which keep low values for the coefficient. This convergence is not simply a general upward trend, since some countries had a high value of the R&D coefficient in the 1970s (France, the US and Canada). A more or less regular increase characterises here again Germany and Japan.

The financial service sector on the other hand seems to exhibit a pattern of divergence since the 1970s. Denmark and the Netherlands are here again characterised by low stagnating R&D coefficients. France, Germany and the US seem to evolve in parallel, with the R&D intensity staying approximately at the same values after the 1980s. Two countries have experienced a strong rise in the R&D intensity : Japan and the UK. This result is not surprising for the UK since finance is an important activity in Great Britain and London is the major financial place in Europe, but it is more surprising in the case of Japan, considering that this country is not renowned for the efficiency of its financial services. However, the interpretation of a high R&D intensity in this country should be taken as a sign of heavy investment in IT equipment in order to catch up to the productivity level of other developed countries in these services rather than an indication of a high level of productivity or innovation. Such a result reminds us that one should be cautious in the interpretation

of high indirect R&D intensities. A high intensity does not constitute *per se* an indicator of technological level but an indicator of the evolution of technology.

Figure 3. The evolution of R&D intensity in financial services

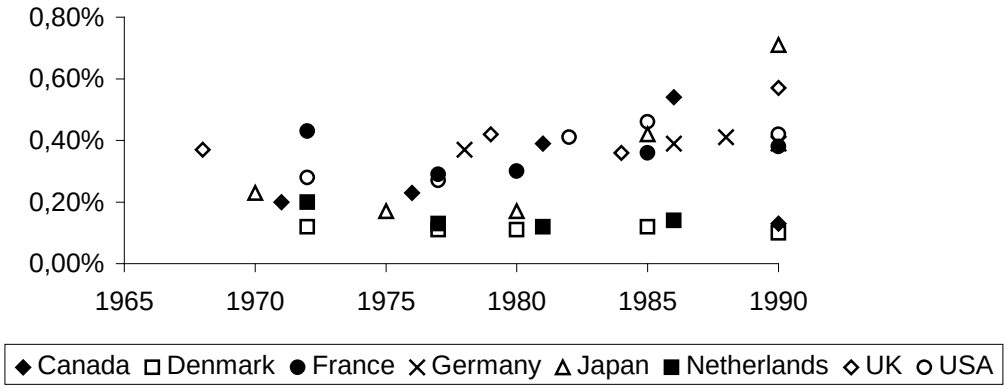
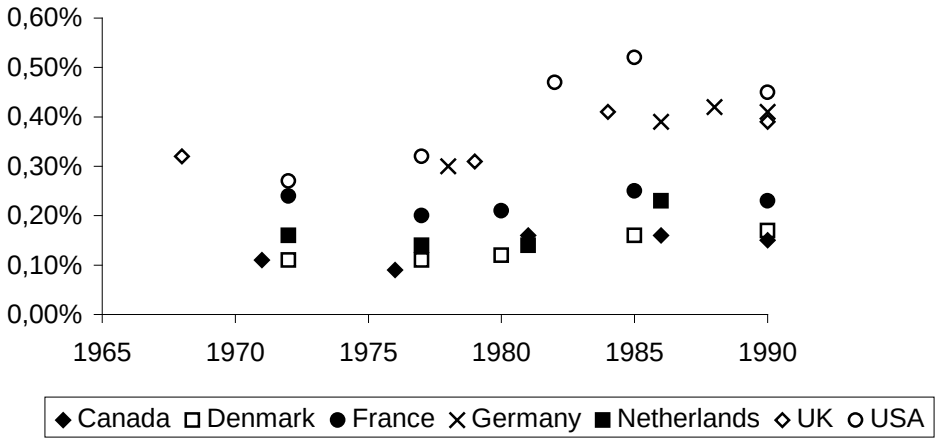


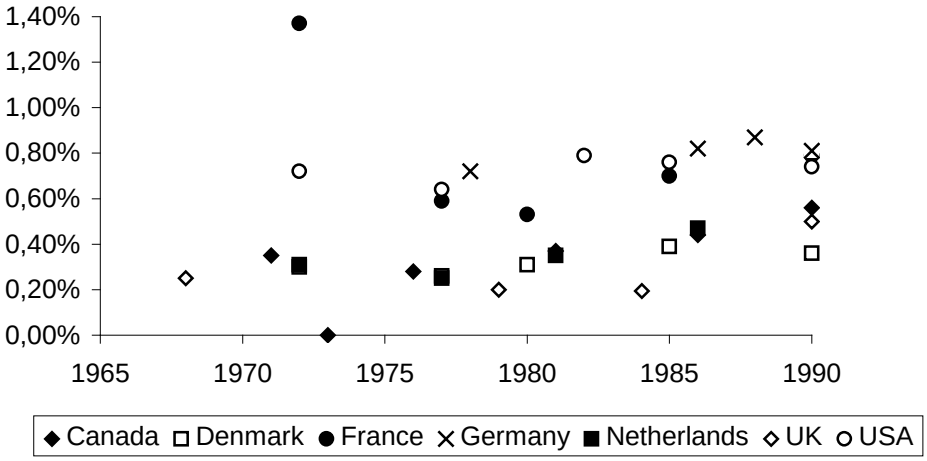
Figure 4. The evolution of R&D intensity in trade and hotels



There is no pattern of convergence or divergence in the R&D intensities as far as the trade and hotels sub-sector is concerned. All countries seem to evolve in parallel, with a general rise of the coefficient between 1975 and 1985.

Ignoring the French coefficient of the early 1970s, R&D intensity in governmental and social services seems to follow an upward trend, with no tendency to convergence to similar values. The hierarchy of countries did not change much over the period.

Figure 5. The evolution of R&D intensity in governmental and social services



IV. Foreign versus domestic sources of incorporated R&D

One may distinguish intermediates and equipment used by the service sector according to the country of origin, or more generally whether they are domestic or come from abroad. Therefore, it is possible to isolate R&D incorporated in domestically produced goods from R&D embodied in imports. Table 4 gives the percentage of domestic R&D relatively to total R&D and Table 6 gives the ranking of countries according to the domestic share. One may note that in all countries, domestic incorporated R&D plays a stronger role in manufacturing and generally in the primary sector too than in services

Two countries stand out : Japan and the US, for which domestic R&D accounts for over 90% of all incorporated R&D (Figure 6). This predominance of domestic sources of R&D is not limited to the service sector, all economic activities in these two countries rely on domestic R&D. The share of domestic R&D for medium-sized countries (France and the UK) is around 50 to 60% and under 50% for the smaller countries. Germany is an intermediate case between Japan and the US on one side, France and the UK on the other side. Overall, the service sector is more dependant on imported R&D than industry.

Another observation is that the countries with the higher R&D intensity in the service activities are more or less those where the domestic share of R&D is higher : Japan, US and Germany[22]. One may wonder whether the domestic access to intermediate and equipment producers is easier than to foreign producers, and whether this makes easier the diffusion of technological change incorporated in new equipment. This correlation is not valid for every activity and every country. For instance, financial services in the UK are characterised by a high R&D intensity, but the domestic sources of R&D only account for slightly over one third of total incorporated R&D. In general, the UK has seen an important increase in the share of imported incorporated R&D in total incorporated R&D, but this trend was more

[22] See Table 2 above.

pronounced for services than for manufacturing or agriculture, and within the service sector for financial services.

Table 3. Share of domestic incorporated R&D in total R&D in 1990*

	Canada	*Denmark*	*France*	*Germany*
Transportation services	46,70%	36,13%	49,55%	58,29%
Communications services	70,97%	56,06%	79,96%	81,45%
Financial services	39,15%	71,58%	50,78%	80,52%
Trade and hotels	44,83%	51,24%	75,23%	78,30%
Social and governmental services	34,78%	39,63%	56,74%	81,19%
Trade, hotels, Social and governmental services	39,08%	43,47%	64,66%	80,11%
Total industry	60,46%	71,07%	81,41%	88,46%
Primary sector	57,51%	52,41%	73,10%	81,61%
Manufacturing sector	67,25%	80,50%	88,89%	91,32%
Private services sector	45,90%	48,40%	60,33%	77,61%
	Japan	Netherlands	UK	USA
Transportation services	89,61%	22,04%	45,85%	90,57%
Communications services	91,04%	38,52%	60,74%	92,17%
Financial services	92,58%	65,53%	37,83%	90,27%
Trade and hotels		34,30%	52,00%	91,63%
Social and governmental services		39,96%	61,64%	89,45%
Trade, hotels, Social and governmental services	93,73%	37,70%	57,65%	90,68%
Total industry	96,47%	67,75%	74,77%	94,90%
Primary sector	97,81%	42,96%	66,85%	91,19%
Manufacturing sector	97,40%	75,33%	82,50%	96,24%
Private services sector	94,11%	37,67%	52,35%	90,79%

A : Transportation services ; B : Communications services ; C : Financial services ; D1 Trade and hotels ; D2 : Social and governmental services ; D = D1 + D2
* except for the Netherlands (1986).

Generally, small and medium-sized countries are characterised by differences in the importance of domestic sources of R&D according to the sub-sector considered. Germany has a very high share of domestic R&D except in transportation services. Imported R&D is less important for the communication and trade and hotels sub-sectors in France. Denmark and the Netherlands rely more on domestic sources of R&D for the financial service sector.

The communication service sector is characterised by an above average share of domestic R&D on the whole 1970-1990 period for all countries.[23] The transportation services sector on the other hand relies more on imported R&D. One interpretation is that the type of technology used, directly and indirectly, in communication services has been for a large part developed domestically, which is not the case for transports. One may suspect that the techniques involved in the two types of activities are to a large extent different.

[23] See Appendix C, Figure A.1 to A.16.

Table 4. Ratio of domestic R&D by sub-sector to domestic R&D in the service sector in 1990*

	Canada	Denmark	France	Germany
Transportation services	1,02	0,75	0,82	0,75
Communications services	1,55	1,16	1,33	1,05
Financial services	0,85	1,48	0,84	1,04
Trade and hotels	0,98	1,06	1,25	1,01
Social and governmental services	0,76	0,82	0,94	1,05
Trade, hotels, Social and governmental services	0,85	0,90	1,07	1,03
	Japan	**Netherlands**	**UK**	**USA**
Transportation services	0,95	0,59	0,88	1,00
Communications services	0,97	1,02	1,16	1,02
Financial services	0,98	1,74	0,72	0,99
Trade and hotels	0,00	0,91	0,99	1,01
Social and governmental services	0,00	1,06	1,18	0,99
Trade, hotels, Social and governmental services	1,00	1,00	1,10	1,00

* except for the Netherlands (1986).

Financial sectors usually depend largely on imported R&D, at least for small and medium-sized countries, except in Denmark and the Netherlands, two countries where the R&D intensity is low, especially in this sub-sector, when one considers the whole 1970-1990 period. Therefore, in spite of being highly open economies, one does not notice for these two countries that R&D 'imports' come as a complement to a somewhat low contribution of domestic sources. Financial services in these countries does not seem to resort to modern (imported) technology, which may indicate a low level of internationalisation of these countries in the financial activity.

Figure 6. The relative importance of domestic R&D

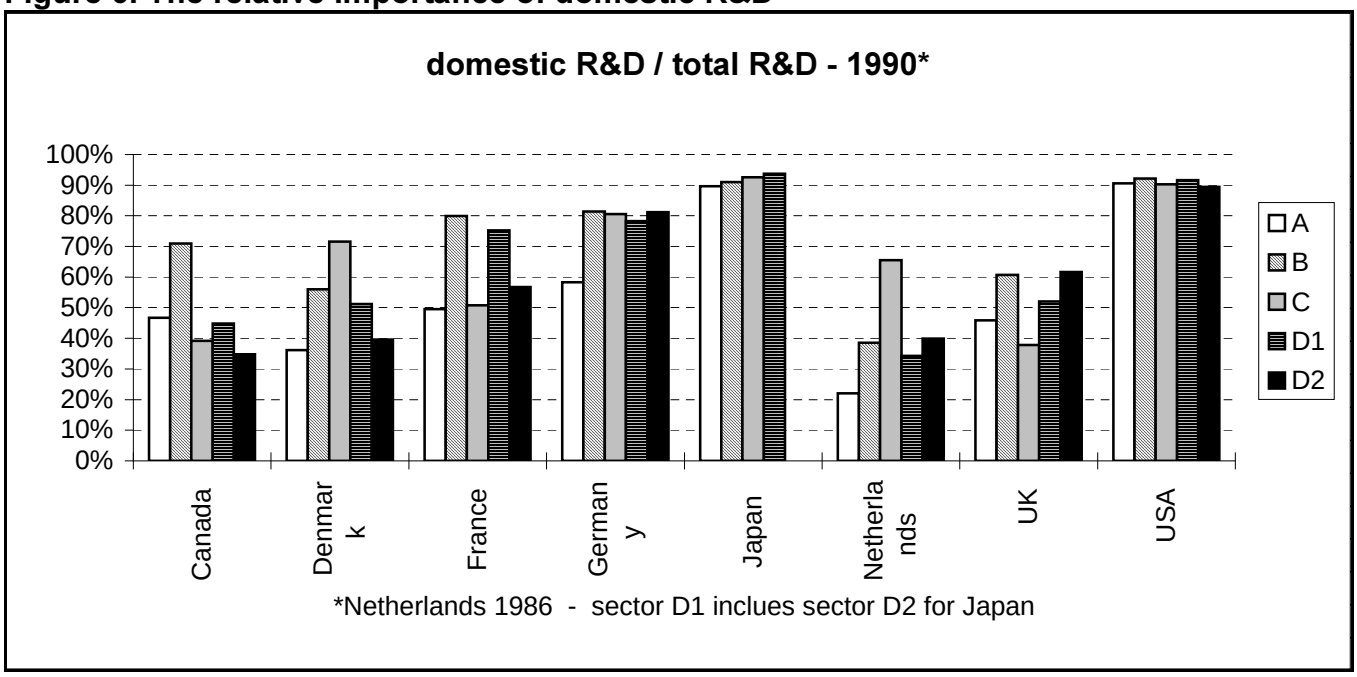


Table 5. Ranking of countries according to the share of domestic R&D

Transportation services	USA, Japan, Germany, France, Canada, UK, Denmark, Netherlands
Communications services	USA, Japan, Germany, France, Canada, UK, Denmark, Netherlands
Financial services	Japan, USA, Germany, Denmark, Netherlands, France, Canada, UK
Trade and hotels	USA, Germany, France, UK, Denmark, Canada, Netherlands
Social and governmental services	USA, Germany, UK, France, Netherlands, Denmark, Canada
Trade, hotels, Social and governmental services	Japan, USA, Germany, France, UK, Denmark, Canada, Netherlands

V. Comparison between France and Germany

France and Germany are quite similar with respect to their pattern of incorporation of R&D in the service sector. In fact, the same could be said about the manufacturing sector taken as a whole, but not for agriculture (Table 1). Germany has a slightly higher R&D intensity than France, particularly in the trade and hotels sector. This is probably due to the difference in the average size of firms in this sector. Larger hotels in Germany have more heavily invested in TIC than small French hotels for instance. For the rest, French and German specialisation patterns are almost identical (importance of Finance and relative weakness in transportation services).

A notable difference concerns the relative importance of domestic and foreign origins of R&D. France is generally less autonomous than Germany. The difference concerns mostly the financial and social and governmental services. French domestic R&D accounts for roughly 50% of total R&D whereas this figure is in the range of 80% for Germany. Nearly all the difference is explained by a greater reliability of France on intermediates and equipment imported from the US (20% of total R&D has an American origin for France, 4% for Germany). A much smaller contribution of Japanese imports also explains some of the difference for the financial services sector.

The observation of the relative shares of domestic and imported incorporated technology since the beginning of the 1970s reveals different patterns for France and Germany. Both countries see imported R&D grow for all services, but the magnitude of the evolution differs widely. Table 8 gives the evolution for financial services and social and governmental services. Imported R&D was largely substituted to domestic R&D in France, this R&D being incorporated in intermediates and equipment from the US and to a lesser extent from Japan, for financial services. This greater reliance on imports does not give France a higher R&D intensity for these activities. It simply reflects the fact that the industrial structure is different in France and in Germany.

In Germany, the chemical sector accounts for 5 times as much as in France as far as its contribution to total R&D intensity in the financial services sector is concerned (0.10% in Germany, 0.02% in France). On the other hand, the computer sector has a contribution in France which is three times as high as in Germany (0.18% vs 0.06%). All in all, the total R&D coefficient is the same in both countries (0.38% and 0.39%). Out of the contribution of the chemical sector to financial services in Germany, 90% have a domestic origin. On the other hand, 90% of the

contribution of the computer sector to French financial services is imported. Therefore, Germany can rely on its strong domestic chemical sector to provide a technological input, even to financial services ! France, on the other hand, relies on importing US computers.

Table 6. Decomposition of incorporated R&D

From	**Domestic**		**France**		**Germany**	
to	*France*	*Germany*	*France*	*Germany*	*France*	*Germany*
Transportation services	49.55%	58.29%	-	18.73%	9.54%	-
Communications services	79.96%	81.45%	-	2.15%	3.03%	-
Financial services	50.78%	80.52%	-	1.83%	4.38%	-
Trade and hotels	75.23%	78.30%	-	1.64%	6.40%	-
Social and governmental services	56.74%	81.19%	-	4.10%	6.49%	-
From	**Italy**		**Japan**		**Netherlands**	
to	*France*	*Germany*	*France*	*Germany*	*France*	*Germany*
Transportation services	1.82%	0.63%	0.86%	1.04%	0.35%	0.42%
Communications services	0.94%	0.56%	2.08%	2.67%	0.26%	1.06%
Financial services	1.87%	0.63%	4.72%	2.35%	0.30%	1.21%
Trade and hotels	1.82%	0.66%	1.82%	2.56%	0.53%	0.82%
Social and governmental services	1.22%	0.47%	1.88%	1.91%	0.44%	0.81%
From	**UK**		**USA**		**Rest of**	**the world**
to	*France*	*Germany*	*France*	*Germany*	*France*	*Germany*
Transportation services	2.42%	2.09%	24.57%	14.43%	10.90%	4.38%
Communications services	1.72%	1.65%	5.57%	2.50%	6.43%	7.96%
Financial services	3.69%	1.91%	22.44%	3.91%	11.81%	7.64%
Trade and hotels	1.69%	2.08%	3.73%	5.81%	8.79%	8.12%
Social and governmental services	2.61%	1.38%	21.35%	4.74%	9.26%	5.41%

The pattern is somewhat different in the social and governmental service sector. Once again, the total R&D intensity is almost the same in both countries (0.79% and 0.81%), and the German chemical sector plays a role which has no genuine equivalent in France. But aerospace has an influence too. This sector contributes to a large extent to incorporated R&D in both countries (0.26% in France, 0.20% in Germany), but this contribution is 75% domestic in Germany whereas it 75% imported in France.

Table 7. The evolution in France and Germany

	Financial services			Social and governmental services	
	Domestic R&D /Total R&D			Domestic R&D /Total R&D	
	FRANCE	GERMANY		FRANCE	GERMANY
1977	74.48%		1977	79.83%	
1978		88.36%	1978		86.04%
1980	71.10%		1980	72.77%	
1985	58.75%		1985	64.59%	
1986		84.11%	1986		81.25%
1988		82.70%	1988		84.04%
1990	50.78%	80.52%	1990	56.74%	81.19%

	Financial services			Social and governmental services	
	R&D USA/Total R&D			R&D USA/ Total R&D	
	FRANCE	GERMANY		FRANCE	GERMANY
1972	10.44%		1972	20.25%	
1977	12.22%		1977	8.96%	
1978		2.84%	1978		4.62%
1980	14.10%		1980	17.11%	
1985	22.07%		1985	20.93%	
1986		3.80%	1986		5.27%
1988		3.70%	1988		2.57%
1990	22.44%	3.91%	1990	21.35%	4.74%

	Financial services			Social and governmental services	
	R&D Japan/ Total R&D			R&D Japan/ Total R&D	
	FRANCE	GERMANY		FRANCE	GERMANY
1977	0.59%		1977	0.40%	
1978		0.63%	1978		0.47%
1980	0.75%		1980	0.71%	
1985	1.94%		1985	1.17%	
1986		1.67%	1986		1.32%
1988		2.13%	1988		1.57%
1990	4.72%	2.35%	1990	1.88%	1.91%

Conclusion

This paper has tried to present an assessment of the incorporation of technology in the service sector, distinguishing between activities within the tertiary sector. Such a disaggregation is imposed by the fact that the broad distinction between primary, secondary and tertiary sectors is largely obsolete. Changes in production methods and technological or organisational innovation in general make the distinctions between the three sectors increasingly unclear. The diffusion of information and communication technologies will contribute to blurring the distinction

between manufacturing and services, as emphasised in Wyckoff [1996].[24] For instance, the mode of delivery of a product may change the classification of the activity concerned from manufacturing to services. When a software producer uses a physical support such as floppy disks for delivery, its activity is classified as manufacturing. It is however classified as a service activity when the software is downloaded via internet.

One must interpret the results presented above with care for several reasons. Data availability problems have limited our investigations to R&D expenditures incorporated in equipment, the allocation of R&D inputs being made with the help of input/output tables. The use of many other indicators would enrich the analysis of the innovative process within the service sector. The other data used in the analysis suffer from various flaws as well : lack of precision in the sectoral definitions, reliability of the data, uncorrected differences in National accounting procedures... Nevertheless, it is always the case when one deals with statistics, and particularly in the service sector, and even more so when one deals with research or innovation. Therefore, the tentative conclusions one can draw from our exercise should lead to further research.

A first result from the analysis is that some service activities incorporate as much if not more R&D as some manufacturing industries, and sensibly more than agriculture. Second, the activities that can be classified as relatively technology intensive within the service sectors are identical across countries. Third, some national differences can be found across sectors: the service sectors in Japan, the US and Germany for instance appear as larger technology users than in other countries. Fourth, some countries are specialised in more technologically intensive (and one may suspect more innovative) service activities than others: Japan, the UK and Canada, and to a lesser extent the US. This specialisation is relative to the position of the service sector as a whole within each country, and should not be mistaken with a measure of competitiveness. Fifth, sectoral differences persist when one looks at the dynamic evolution of R&D coefficients. Sixth, one finds some convergence in the R&D intensity of the communication services, which somehow reflects the pervasiveness of the IT paradigm, but no such pattern can be found for other service activities. There is some degree of divergence or convergence for some clubs of countries in the financial services for instance.

Last, the comparison between France and Germany, two countries with a great deal of similarity in their service specialisation as well as R&D intensity in the service sector, reveals the importance of domestic versus foreign sources of technology. The differences in industrial structure and reliance on foreign trade for inputs explain different patterns of technology incorporation and diffusion of technical change for the financial services and governmental and social services. The greater reliance of France on (indirectly) imported technology finds its origins on differences in the industrial structure (the importance of the chemical sector in Germany) and the importance of the US as a supplier for France.

[24] See also Hauknes and Miles [1996].

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APPENDIX

A Total R&D intensity

The methodology for deriving total R&D intensities comes from OECD [1996]. Total R&D intensities are defined as the sum of direct and indirect R&D expenditures divided by the production of the sector. Indirect R&D is that embodied in the products purchased by a sector as intermediate inputs and equipment goods. The concept of R&D embodiment can be traced back to Terleckyj [1974] and relies on the idea that purchased goods are the carriers of technology flows. Input-output coefficients can then be used to assess the amount of technology that flows between sectors.

The input-output system can be defined as :

$$X = A.X + F + E$$

X is the vector of gross outputs, A is the matrix of domestic input-output coefficients, F is the vector of final demand and E is the exports vector. Solving the system for X gives the well-known equation :

$$X = (I - A)^{-1}.[F + E]$$

Direct R&D intensity for each sector is defined as the ratio of total R&D expenditures to gross output

$r_i = R_i/X_i$

The vector of total R&D embodiment T is defined as :

$T = \hat{r} (I - A)^{-1} [F + E]$

and $\hat{r}$ is the diagonalised matrix of sectoral R&D coefficients. The total domestic R&D embodiment per unit of final demand for industry j can be defined as the j-th column sum of the $\hat{r} (I - A)^{-1}$ matrix. The Leontief inverse matrix $(I - A)^{-1}$ measures the direct and indirect impacts on domestic production when final demand changes. By pre-multiplying by $\hat{r}$, one obtains the total amount of R&D per unit of the final delivery of output of each sector.

The calculation of total R&D embodiments in purchased intermediate goods for each sector involves a modified Leontief inverse matrix. The traditional Leontief multiplier tells how much R&D is directly and indirectly embodied in one unit of final demand for each sector, but not how much is embodied in gross output. In order to redefine R&D embodiments on a gross output basis, one needs to define output to output multipliers.

Defining A_{-j} as the A matrix without the line and the column corresponding to sector j, and $\mathbf{a}_j$ the j-th column vector of the A matrix minus the j-th line, one defines vector $\mathbf{b}_j$ as:

$$\mathbf{b}_j = (I - A_{-j})^{-1} \mathbf{a}_j$$

The above defined vector indicates how much direct and indirect output requirements from all sectors except j is necessary to produce one unit of output for sector j. The B* matrix is then defined as B* = [$\mathbf{b}_1$',$\mathbf{b}_2$',...,$\mathbf{b}_n$'], and the $\mathbf{b}_j$' vectors are the $\mathbf{b}_j$ vectors with a 0 at the j-th line. The use of the modified Leontief multiplier instead of the traditional multiplier avoids the problem of double counting the R&D embodiment of each sector and the total R&D embodiment of each sector can be defined as the simple sum of direct R&D actually conducted by the sector and R&D embodied in purchased products.

R&D embodied in intermediates is defined as :

$$T_{int} = \hat{r} B^* X$$

and R&D embodied in purchased capital goods is defined as :

$$T_{inv} = \hat{r} B^* I$$

Where I is the vector of investment expenditures.

Imported R&D is defined simply by multiplying foreign direct R&D intensities with the imported amount of intermediate demand and capital goods. The interindustry propagation effects of acquired R&D are not taken into account because of the complexity of the calculations involved.

B The production and employment shares of each service sector

One may try to assess the relative specialisation of each country by looking at the share of each service activity in total services production and employment (Tables A.1a and A.1b). A first observation is that communication services are a minor part of the production of the whole service sector, in any case less than 4% of total service production and employment. From a relative point of view, one notices that the in the UK, the USA and Canada communication services have a more important weight in production than in other countries, France and Germany are specialised in financial services, Denmark and Japan are specialised in transportation services while the Netherlands are specialised in social services. The pattern of specialisation of Japan cannot be assessed as precisely as for the other countries because of the lack of data within the 'D' (trade, hotels, governmental and social services) sub-sector.

One aspect separates the USA from the other countries: the very low share of social and governmental services. From this point of view, no other country, not even Canada or the UK can be assimilated to the US. It should also be noted that according to OECD statistics, the item *Producers of Government services*, which is used in the definition of the item **D2**, *Social and Governmental Services*, has a more restrictive definition in US National Accounts than in OECD National Accounts.

Table A1a. The share of each sub-sector in the total services production in 1990* and specialisation indices

	Canada	**Denmark**	**France**	**Germany**
Transportation Services	9.59%	12.58%	6.74%	6.52%
Communication Services	3.58%	2.74%	2.55%	2.78%
Financial Services	25.12%	27.13%	38.08%	38.53%
Trade and Hotels	26.41%	19.04%	22.54%	19.41%
Social and Governmental Services	35.30%	38.52%	30.07%	32.76%
	Japan	**Netherlands**	**UK**	**USA**
Transportation Services	12.10%	9.14%	9.50%	7.29%
Communication Services	2.22%	2.88%	3.84%	3.52%
Financial Services	30.68%	24.25%	29.12%	38.95%
Trade and Hotels	55.01%	25.49%	23.79%	28.30%
Social and Governmental Services	*(D1=D1+D2)	38.25%	33.74%	21.94%
	INDEX OF SPECIALISATION-1990 (a)			
	Canada	**Denmark**	**France**	**Germany**
Transportation Services	1.04	1.37	0.73	0.71
Communication Services	1.19	0.91	0.85	0.92
Financial Services	0.80	0.86	1.21	1.22
Trade and Hotels	1.12	0.81	0.96	0.82
Social and Governmental Services	1.07	1.17	0.91	0.99
	Japan	**Netherlands**	**UK**	**USA**
Transportation Services	1.32	1.00	1.03	0.79
Communication Services	0.74	0.96	1.28	1.17
Financial Services	0.97	0.77	0.93	1.24
Trade and Hotels	0.97	1.08	1.01	1.20
Social and Governmental Services	(D1=D1+D2)b	1.16	1.02	0.67

(a) The index of specialisation is defined as the ratio of the share of each sub-sector to the average share of that sector across all countries.

(b)The figures reported for Trade and Hotels for Japan also include the Social and governmental services.

* except for the Netherlands (1986).

Table A.1b the share of each sub-sector in the total services employment in 1990*

	Canada	**Denmark**	**France**	**Germany**
Transportation Services	5,72%	7,90%	5,77%	6,60%
Communication Services	3,40%	2,68%	3,00%	3,21%
Financial Services	16,32%	14,98%	16,38%	*61,50%*[$]
Trade and Hotels	33,81%	19,31%	26,74%	28,69%
Social and Governmental Services	40,75%	55,13%	48,10%	
	Japan	**Netherlands**	**UK**	**USA**
Transportation Services	10,33%**	7,52%	-	4,36%
Communication Services	**(A=A+B)	2,26%	-	1,46%
Financial Services	9,77%	17,17%	-	20,28%
Trade and Hotels	79,90%***	29,36%	-	31,64%
Social and Governmental Services	***(D1=D1+D2)	43,69%	-	42,26%

*except for the Netherlands (1986). **includes Communication services. ***includes Social and Governmental Services. [$]includes Social and Governmental Services.

It is also possible to assess relative productivity levels for each service sub-sector. Cross-country comparisons of productivity levels are well beyond the range of this article, which is why only intra-country comparisons are presented in Table A2. Some facts are remarkable: the high relative levels of communication services in the USA, financial services in Japan and France, or the low productivity of social and governmental services in the US.

Table A2. Relative productivity level (w.r.t. the average productivity level for the whole service sector) in 1990*

	USA	Canada	Japan	Germany	France	Netherlands	Denmark
Transportation services	1,67	1,68		0,99	1,17	1,22	1,59
Communication Services	2,41	1,05		0,87	0,85	1,27	1,02
Financial Services	1,92	1,54	3,14		2,32	1,41	1,81
Trade and Hotels	0,89	0,78		0,68	0,84	0,87	0,99
Social and Governmental Services	0,52	0,87			0,63	0,88	0,70
Transportation and Communication services			1.39				
Trade, hotels, Social and governmental services			0.69				
Financial, social and governmental services				1.16			
TOTAL	1,00	1,00	1,00	1,00	1,00	1,00	1,00

* except for the Netherlands (1986).

C. Share of domestic incorporated R&D

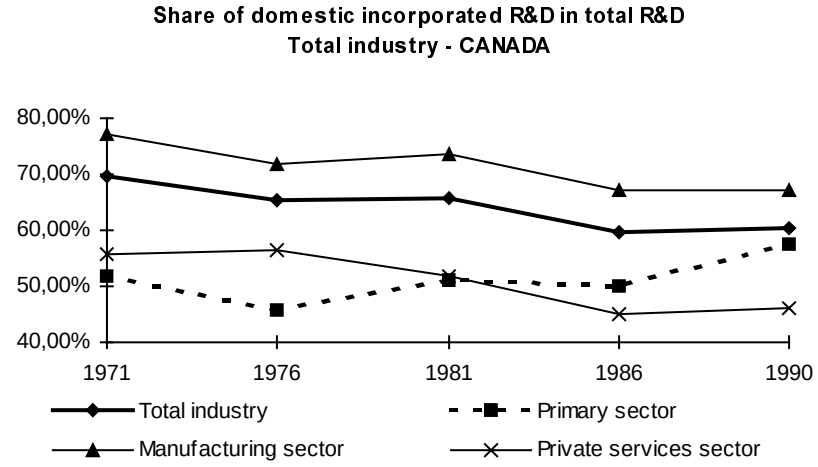


Figure A.1

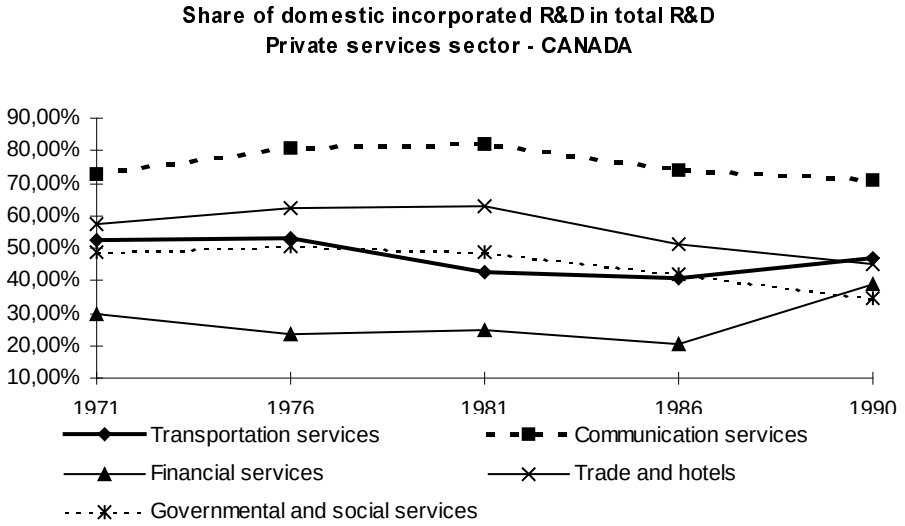


Figure A.2

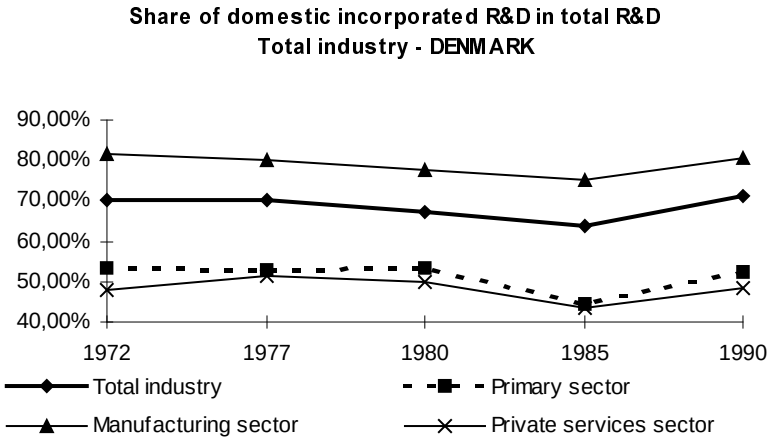


Figure A.3

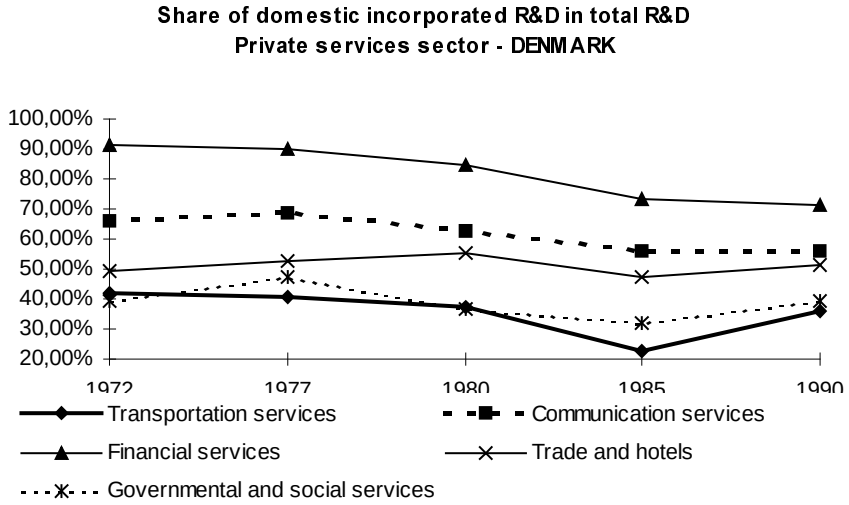


Figure A.4

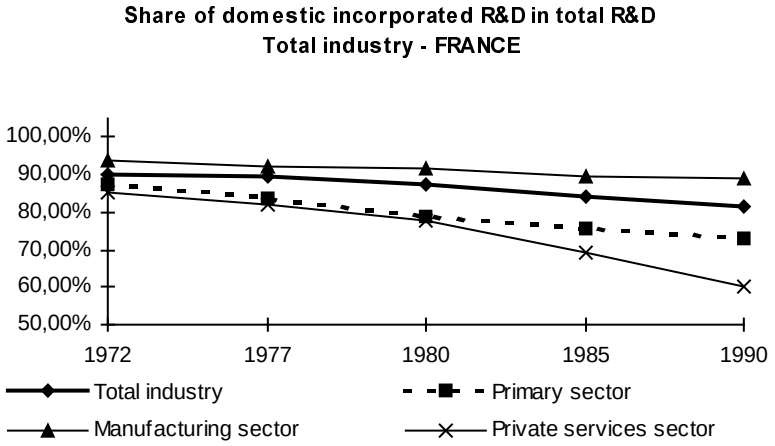


Figure A.5

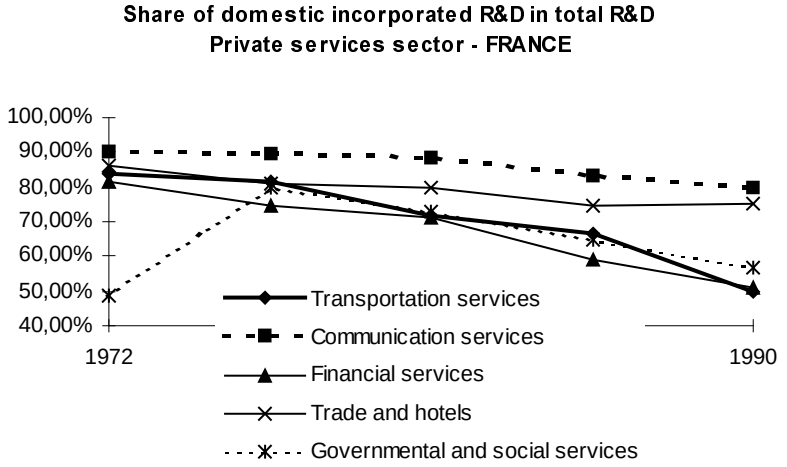


Figure A.6

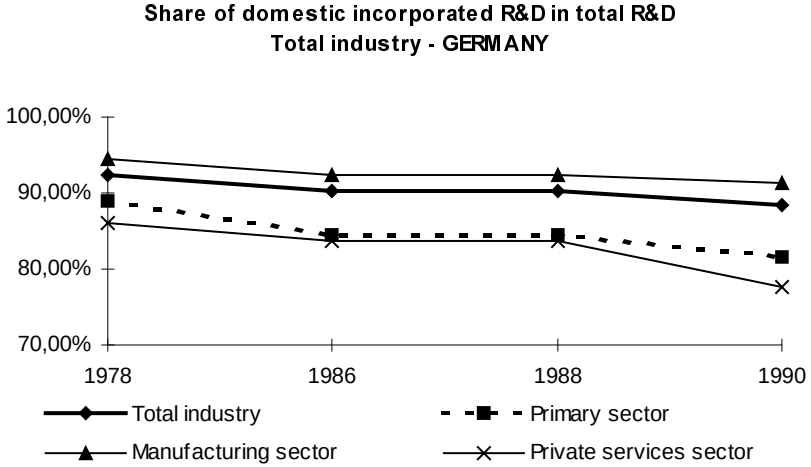


Figure A.7

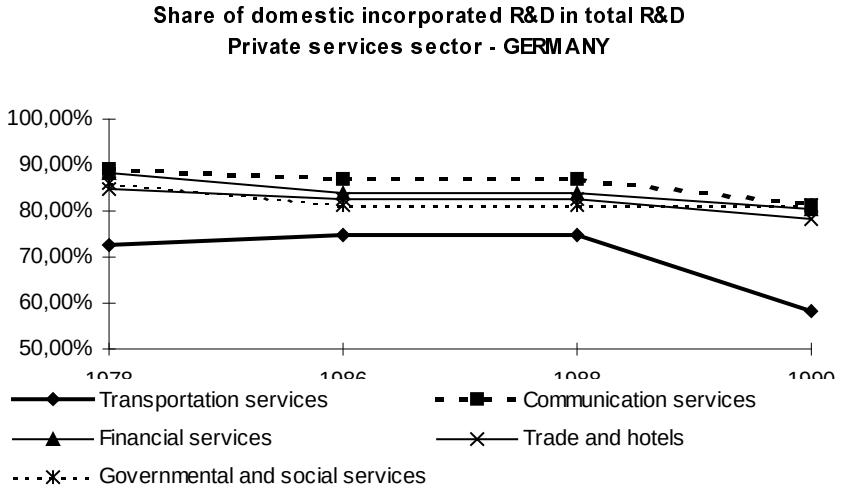
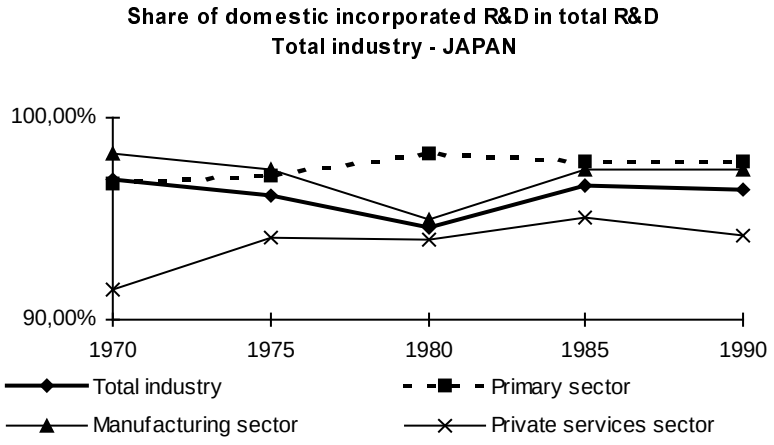


Figure A.8



Figue A.9

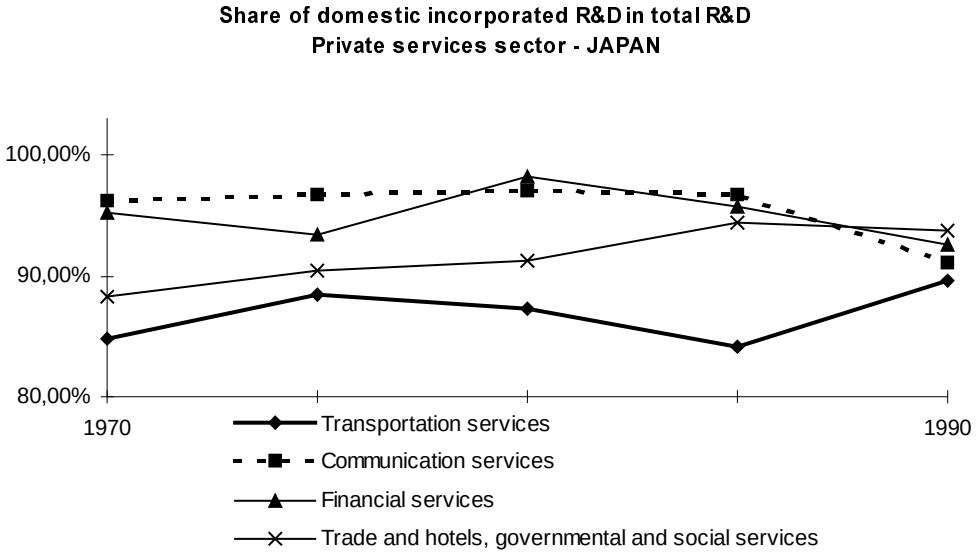


Figure A.10

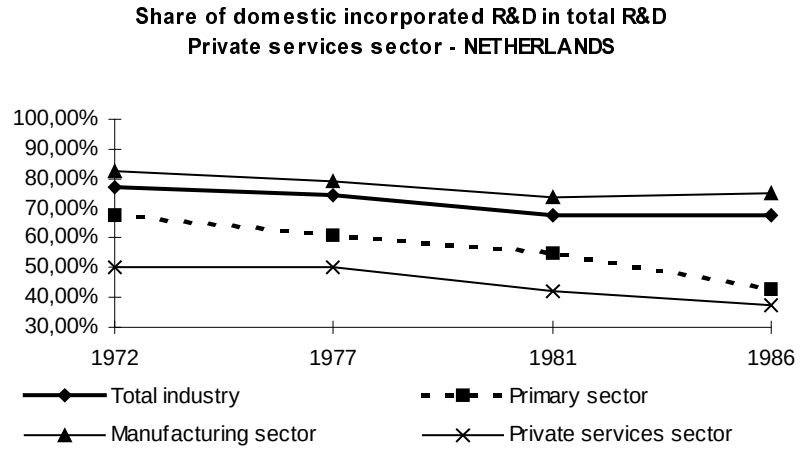
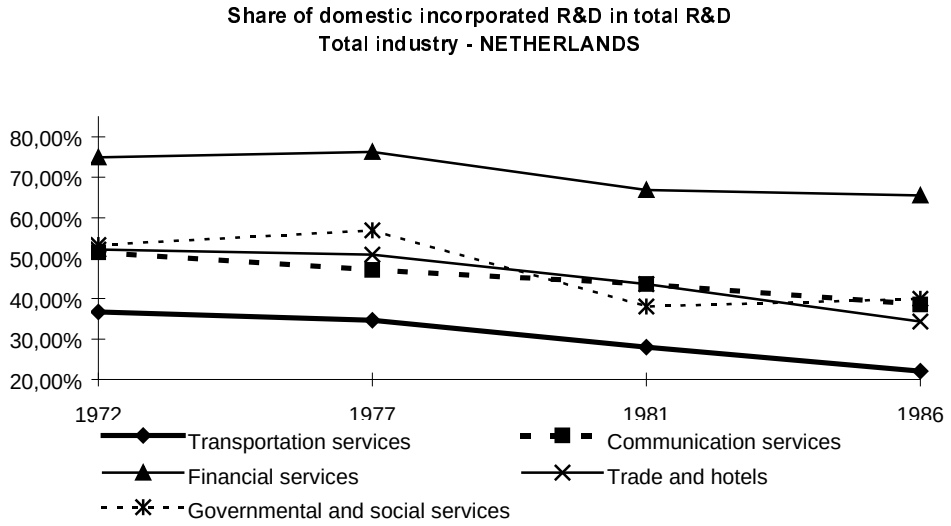


Figure A.11



Figue A.12

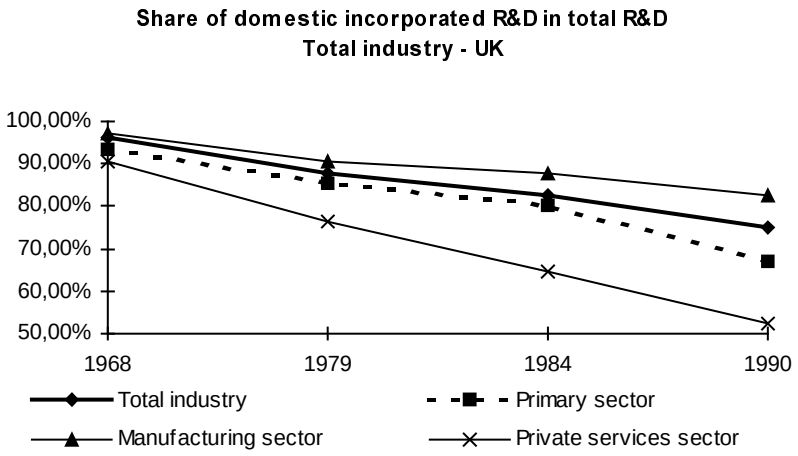


Figure A.13

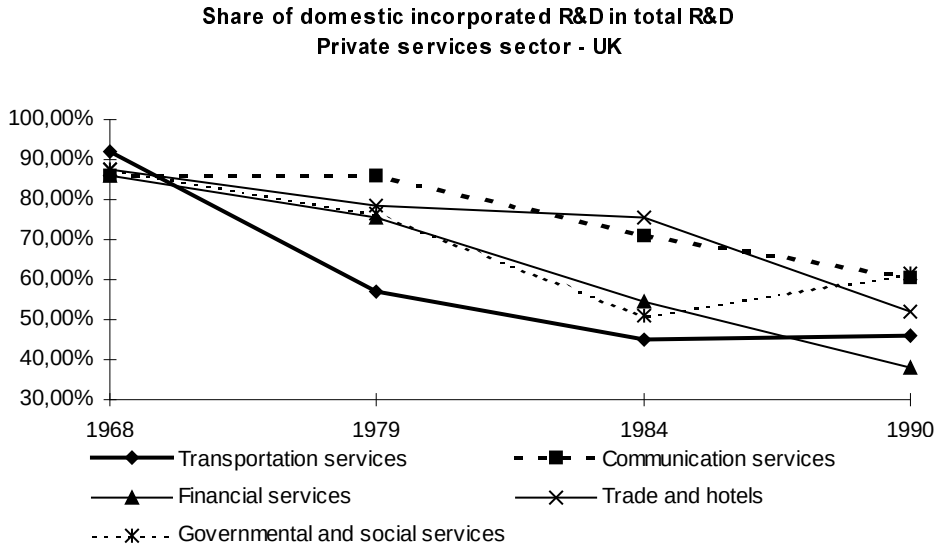


Figure A.14

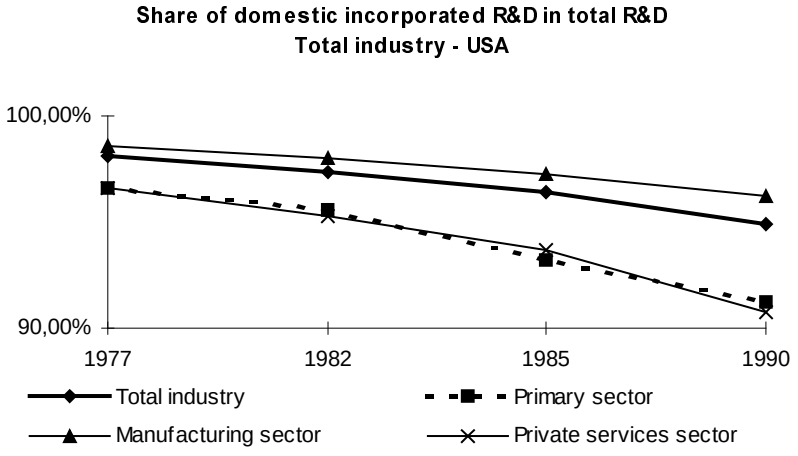


Figure A.15

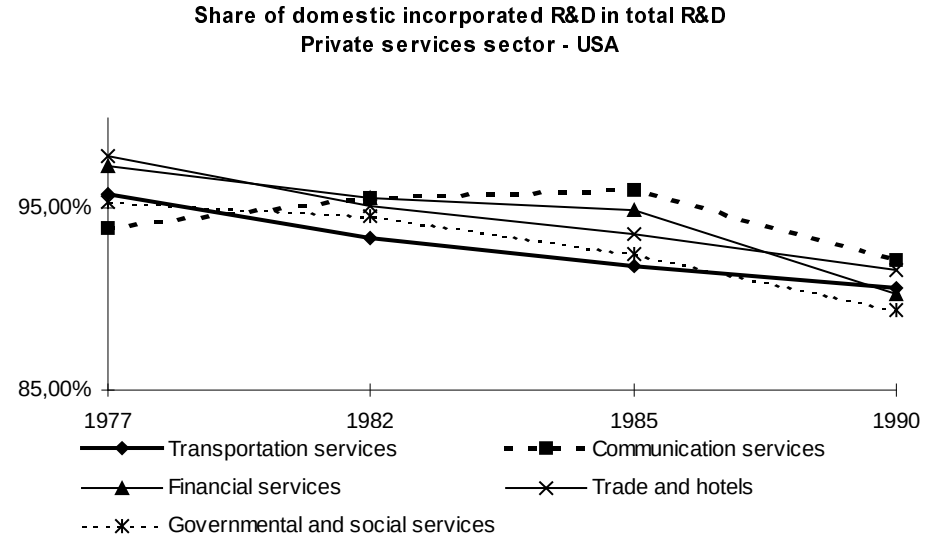


Figure A.16