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REVISION OF THE HIGH-TECHNOLOGY SECTOR AND PRODUCT CLASSIFICATION

Thomas Hatzichronoglou

This paper describes the methods used to classify the OECD countries' industrial sectors and manufactures by level of technology, and presents the resulting classifications. In the proposed new classification by industrial sector, the concept of technology intensity has been expanded to take into account both the level of technology specific to the sector (measured by the ratio of R&D expenditure to value added) and the technology embodied in purchases of intermediate and capital goods. Four groups of industries have been identified on the basis of the degree of technology intensity.

The classification by product consists solely of high-technology products (products which are the most technology-intensive). The classification was drawn up by the OECD Secretariat in collaboration with Eurostat, the object being to finalise the approach by sector and provide a more appropriate instrument for analysing international trade. Because no detailed data were available for services, the two proposed classifications concern only manufacturing industry.

RÉVISION DES CLASSIFICATIONS DES SECTEURS ET DES PRODUITS DE HAUTE TECHNOLOGIE

Thomas Hatzicronoglou

Ce document expose les méthodes pour classer les secteurs industriels et les produits manufacturés des pays de l'OCDE selon leur intensité technologique et présente les classifications qui en résultent. Dans la nouvelle classification proposée par secteur industriel, la notion d'intensité technologique a été élargie pour tenir compte *à la fois* de l'effort technologique propre au secteur (mesuré par le ratio des dépenses de R-D sur la valeur ajoutée) et de la technologie incorporée dans les achats de biens intermédiaires et d'équipement. Quatre groupes d'industries ont été identifiés en fonction du niveau de leur intensité technologique.

La classification par produit se réfère exclusivement aux produits de haute technologie (produits dont l'intensité technologique est la plus élevée). Cette classification a été élaborée par le Secrétariat de l'OCDE en coopération avec Eurostat, afin de compléter l'approche par secteur et fournir un instrument plus approprié pour l'analyse des échanges internationaux. Du fait de la non disponibilité de données détaillées sur les services, les deux classifications proposées concernent exclusivement l'industrie manufacturière.

INTRODUCTION

In the context of economic globalisation, technology is a key factor in enhancing growth and competitiveness in business.

Firms which are technology-intensive innovate more, win new markets, use available resources more productively and generally offer higher remuneration to the people that they employ. High technology industries are those expanding most strongly in international trade and their dynamism helps to improve performance in other sectors (spillover). In order to analyse the impact of technology on industrial performance, it is important to be able to identify those industries and products which are most technology-intensive, through criteria allowing the construction of special internationally harmonized classifications.

This paper sets out the methods which the OECD Secretariat has used to classify sectors and products by level of technology, and presents the resulting classifications.

The OECD Secretariat's early analytical work on high technology, relating particularly to trade,[1] was based on the classification produced in the United States, which was subsequently applied to all OECD countries. Although countries could then, for the first time, be ranked and compared in the high technology field, a drawback of the approach was that it extrapolated the structure of American industry to the whole of the OECD area. That is why, in a second stage, the Secretariat in 1984 developed a new classification using a sample of eleven countries. This classification was based on direct R&D intensity (R&D expenditure in relation to output), weighted by sector and country, and led to a list placing industries in three categories[2] (high, medium and low technology) that has been used extensively by OECD Member countries and many others as well.

The classification had the advantage of providing a simple and consistent tool for international comparisons but it also had limitations, largely due to the lack of sufficiently disaggregated sectoral data. Ten years after the first list was drawn up, the need was felt to review the lessons learned during that period and envisage certain improvements. The latter reflect developments in technology more fully by using much more recent data, and including various aspects of technology diffusion (indirect intensity). The OECD Secretariat has accordingly prepared two new lists: one for *manufacturing industries* (sectoral approach) and the other for *manufactures* (product approach).

The data used to prepare the sectoral list are based on the International Standard Industrial Classification, ISIC Rev. 2. The new classification covers manufacturing industry alone, for which the Secretariat held lengthy and relatively complete series. In the sectoral approach, however, it will ultimately be necessary to include services once appropriate data are available, since services are moving from intensive technology use to become, increasingly, technology producers.

The product approach was developed more recently to supplement the sectoral one and provide a more appropriate tool for analysing international trade. It is based on the Standard International Trade Classification, SITC Rev. 3.

The sectoral approach

The construction of a complete classification of industries according to their technology intensity involves a number of difficulties. The first concerns the criteria for identifying the technology content of an industry. The second concerns the underlying concept. What is a high-technology industry: is it one producing technology, or is it one intensively using technology? A third problem is that there is always some degree of arbitrariness in choosing the cut-off points between the technology classes.

The Secretariat experimented with various criteria to identify the technology content of an industry, but quantification was hampered by the absence of data. As a result, R&D intensity became the sole criterion.[3]

Overcoming the second difficulty called for a comparison of direct and indirect R&D intensity. Two direct intensity indicators were used, and one for overall R&D intensity (sum of direct and indirect intensity). The two direct indicators were constructed for each of the 22 manufacturing sectors in ten OECD countries,[4] and the OECD list was obtained by weighting each sector for its share in the production or value added of all ten countries, taking GDP purchasing power parities as exchange rates. With the overall intensity indicator, direct intensity was calculated in the same way. For indirect intensity, account had to be taken of technology (R&D expenditure) embodied in intermediates and capital goods purchased on the domestic market or imported. Technology moves from one industry (and one country) to another when the industry performing R&D sells its products embodying that R&D to other industries which use them as manufacturing inputs. When calculating indirect intensity, we used the technical coefficients of manufacturing industries, on the basis of input-output matrices. On the assumption that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in production remained constant, the input-output coefficients were multiplied by the direct R&D intensities (see also Annex 1).

These indicators were calculated over a long period (1973-92) but the final classification was constructed for 1980 and 1990 data using these indicators in such a way that it is stable across all three indicators: industries classified in a higher category have a higher OECD-average intensity for all indicators than industries in a lower category (with one exception, petroleum; see below). Four groups of manufacturing industry were identified as a result: *i)* high-technology, *ii)* medium-high-technology, *iii)* medium-low-technology and *iv)* low-technology.

Taking indirect intensity into account in the calculations is unlikely to affect an industry's classification in any of these groups, but it may modify its ranking. That brings out the fact that industries which devote a high proportion of their turnover or production to R&D also make use of the most advanced equipment and intermediates. For such industries there is a strong ranking between direct intensity (production of technology) and indirect intensity (use of technology).

Last, the cut-offs between the four categories are less arbitrary than they seem. Industries in a higher group are more R&D-intensive than those in a lower group over a long period (1980-92).

The distinction between the medium-high and medium-low groups, and between the medium-low and low groups, is more clearcut when R&D intensity is calculated in terms of production than when it is calculated in terms of value added. In both cases, however, the cut-off points provide stability over time and median stability across countries, *i.e.* industries classified in a higher category have higher median intensity than industries in a lower category.

Table 1. Manufacturing industries classified according their global technological intensity (ISIC Revision 2)

High-technology	CITI Revision 2
1. Aerospace	3845
2. Computers, office machinery	3825
3. Electronics-communications	3832
4. Pharmaceuticals	3522
Medium-high-technology	
5. Scientific instruments	385
6. Motor vehicles	3843
7. Electrical machinery	383-3832
8. Chemicals	351+352+3522
9. Other transport equipment	3842+3844+3849
10.Non-electrical machinery	382-3825
Medium-low-technology	
11. Rubber and plastic products	355+356
12. Shipbuilding	3841
13. Other manufacturing	39
14. Non-ferrous metals	372
15. Non-metallic mineral products	36
16. Fabricated metal products	381
17. Petroleum refining	351+354
18. Ferrous metals	371
Low-technology	
19. Paper printing	34
20. Textilee and clothing	32
21. Food, beverages, and tabacco	31
22. Wood and furniture	33

The list adopted (Table 1 and Annex 2, Table 3) corresponds to overall R&D intensity (direct and indirect) and is stable throughout the reference period. It differs from the list employed until 1994 in three ways:

- First, the technology intensity of electrical machinery has declined while scientific instrument intensity increased and has in fact, from 1986 onwards, tended towards the levels for the high technology sectors. When intensity is calculated on the basis of value added, the scientific instrument sector is less intensive than the automobile industry, but it is more intensive when the calculation is based on production. For stability over time we decided to withdraw scientific instruments and electrical machinery from the high-technology group, and they are now in the medium-high group.

- Second, within the medium-technology group two sub-categories are shown, corresponding to medium-high and medium-low-technology.

- Third, some sectors formerly classified as low-technology are now in the medium-low category, because their intensity has risen. This is the case, in particular, with shipbuilding. Other sectors (ferrous and non-ferrous metals, fabricated metal products and petroleum refining) have been reclassified following the change from three to four groups. The intensity of petroleum refining is in fact higher than that of electrical machinery when calculated on the basis of value added rather than production. This is the only point on which the classification does not meet the stability criterion, and is probably due to the high proportion of intermediate consumption typical of the sector. The intensity of rubber and plastics has declined over the last 20 years, whereas the intensity of other transport equipment has been rising, coming close to electrical machinery.

The product approach

The product approach supplements the sectoral approach and opens the way to far more detailed analysis of trade and competitiveness.

It differs in at least three ways from the sectoral approach.

While an industry may be very technology-intensive in one country and only slightly technology-intensive in another, it is inconceivable that the same product should be classified as high-tech in some countries and as medium- or low-tech in others. If that were the case, it would imply that the products were different.[5] As a result, the existence of country lists alongside the OECD list can be justified only when, at national level, the list of high-tech products is much more disaggregated.

Second, the product approach includes some products which are not as a rule in the sectoral list since they are manufactured by medium-technology sectors. It also makes it possible to calculate the true proportion of high technology in a given sector, in the sense that the product approach excludes all products that are not high-tech, even if they are manufactured by high-tech industries.

A third feature of the product approach is that it is solely concerned with products in the high- technology category. For the time being medium-high-, medium-low- and low-tech products are not identified, at least at the level of aggregation that has been selected.

In 1994 an initial list was prepared by the Secretariat in conjunction with the Fraunhofer Institute in Germany, corresponding to the three-digit SITC Rev. 3 classification of foreign trade. It was the outcome of calculations concerning R&D intensity by groups of products (R&D expenditure/total sales) covering six countries (the United States, Japan, Germany, Italy, Sweden, the Netherlands).

In the product approach, in contrast to the sectoral one, the number of countries covered is of no great importance since national considerations have no bearing on whether a product is classified as high-tech or not. Accordingly, for a given level of aggregation, a list of high-tech products can be drawn up on the basis of a smaller number of countries.

The list proposed by the Secretariat in 1994 represented an important first step in this new field and served as the basis for subsequent work culminating in the list set out in Table 2. This further work was prompted by three problems raised by the 1994 list.

First of all, the three-digit level of aggregation, although a considerable improvement on the sectoral approach, was still rather limited. Perhaps the greatest shortcoming was the description of the four- and five-digit products from the earlier product groups. Quite clearly, at this level of aggregation many products could not justifiably be considered high-tech, and had to be excluded in subsequent work. Where doubts remained, experts on the products concerned were consulted.

Second, the automobile industry as a whole was classified as high-tech. In the sectoral approach, on the other hand it is considered to be medium-high and it would be hard to justify distinct overall treatment of motor vehicles under the sector approach and under the product approach. Moreover, the significant contribution which motor vehicles make to international trade would radically change the country profile. We therefore decided that it was preferable to exclude motor vehicles from the list of high-technology products.

Third, despite the calculations, the technology content of some products manufactured by medium- and low-technology sectors, even at a more disaggregated level, was not confirmed by expert opinion. Given this dilemma, it was considered preferable to exclude them from the list of high-technology products.

As a result, the proposed list in Table 2 is relatively compatible with the sectoral lists, inasmuch as products have been classified according to the sector to which they belong.[6] It is more restrictive than the previous product list, and much more restrictive than the sectoral lists. On the other hand, it includes some products manufactured by medium-high technology industries.

A new product databank has thus been created for foreign trade using the list in Table 4 (Annex 2). For the first time, a bank of this kind incorporates the unit values of individual products (value/quantity) for total exports and imports and for bilateral trade as well. Further work will provide estimates of product ranges, from the unit values. At the same time, in order to take account of the qualitative aspects of foreign trade, each country's competitiveness, for each product, will have to be thoroughly analysed. That should enable the construction of individual country lists reflecting the range of each product traded.

Since 1994 the five-digit foreign trade classification SITC Rev. 3 has been replaced by the six-digit Harmonized System classification. As a result, the product list may, in the near future, contain more products.

Principal limitations of the lists proposed

Without embarking on a theoretical and conceptual discussion of the measurement of technology itself, and high technology in particular, it is worth mentioning some of the limitations directly connected with the construction of the lists proposed.

The first concerns the criteria employed. Only R&D intensity, whether direct or indirect, has been taken into account. Research is an extremely important characteristic of high technology, but it is not the only one. Other factors can also play a significant part (*e.g.* scientific and technical personnel, technology embodied in patents, licences and know-how, strategic technical co-operation between companies, the rapid obsolescence of the knowledge available, quick turnover of equipment, etc.).

R&D intensity measurements have two other shortcomings as well. They are biased against the sectors and periods in which turnover or production increase more rapidly than R&D expenditure on account of strong demand in growth or exceptionally vigorous marketing. The difficulty, which mainly affects results for given countries in given years, resides in the fact that calculations are based on data for flows, not stocks. In the absence of stock data, this difficulty has been largely overcome by taking the OECD average for each year and each sector.

In the sectoral approach more particularly, R&D intensity can also be skewed because all research in each sector is attributed to the principal activity of the firms making up the sector. Thus, a significant proportion of the aerospace industry's R&D concerns electronics, as is also true of other sectors. Accordingly, the R&D intensity of the aerospace industry will be overestimated, and that of electronics underestimated.

Another limitation which applies more particularly to the sectoral approach is the lack of sufficiently disaggregated data. When 22 sectors are classified in terms of technology intensity, it is unlikely that basically different sector groupings would be obtained, particularly in the high-tech group, even if additional selection criteria were employed.

Table 2. High Technology Products List – SITC Rev. 3
(Period 1988-95)

1.	Aerospace	[7921+7922+7923+7924+7925+79293 +(714-71489-71499)+87411]
2.	Computers-office machines	[75113+75131+75132+75134+(752-7529)+75997]
3.	Electronics-telecommunications	[76381+76383+(764-76493-76499) +7722+77261+77318+77625+7763+7764+7768+89879]
4.	Pharmacy	[5413+5415+5416+5421+5422]
5.	Scientific instruments	[774+8711+8713+8714+8719+87211+(874-87411-8742)+88111+88121 +88411+88419+89961+89963++89967]
6.	Electrical machinery	[77862+77863+77864+77865+7787+77844]
7.	Chemistry	[52222+52223+52229+52269+525+57433+591]
8.	Non-electrical machinery	[71489+71499+71871+71877+72847+7311+73131+73135 +73144+73151+73153+73161+73165+73312+73314+73316 +73733+73735
9.	Armament	[891--]

The principal limitations associated with the lack of detailed data is that many products manufactured by high-technology sectors are medium- or even low-tech, while conversely some of the products made by medium- or low-technology sectors are high-tech.

In principle, it was to overcome this difficulty that the product approach was developed. Even so, the latter has three other limitations of its own. First, high-tech products cannot be selected exclusively by quantitative methods unless a relatively high level of aggregation is adopted. Resorting to expert opinion does make for extremely detailed lists, but the operation as a whole is relatively cumbersome and the results cannot readily be reproduced in their entirety by other panels of experts.

The second limitation relates to the lack of a product hierarchy. If the choice is not based exclusively on quantitative measurements, it is difficult to classify the products in increasing or decreasing order, which depends on their technology content level. It is to overcome this difficulty that the Secretariat has calculated the unit values of exports and imports, and proposes to classify products in terms of range using a special methodology.

A final limitation is that the data are not comparable with other industrial data. With the exception of the new PRODCOM classification for output data, other industrial variables, in particular employment, value added and gross fixed capital formation, are available only at sector level, not by product.

ANNEX 1

Method of evaluation of indirect R&D intensities

a) Estimation of technology flow matrix by country and year

b) Leontief inverse approach

Method of evaluation of indirect R&D intensities

a) Estimation of technology flow matrix by country and by year

The OECD input-output database[7] distinguishes the transaction flows between industries by domestic and imported flows. In addition, commodity components of business gross fixed capital formation is distinguished by industry of origin and are available separately by domestic and imported flows. Based on these accounts, an input-output model to measure the total R&D embodiment can be described in the following manner.

- *R&D embodied in purchased domestic intermediate inputs*

The R&D flows embodied in domestic intermediate product purchased by industry *j* from industry *i*, RII^{d}_{ij} , can be obtained by:

$$RII^{d}_{ij} = \frac{X^{d}_{ij}}{X_i} \cdot R_i = X^{d}_{ij} \frac{R_i}{X_i} \qquad (1)$$

where X^{d}_{ij} represents the quantity of output of industry *i* purchased by industry *j*, X_i the total sales of industry *i*, and R_i is the own R&D expenditures of industry *i*. R_i/X_i is the R&D intensity for sector *i* per unit of gross output of sector *i*. Although it will be very important to take lags of R&D into account (on average 2-3 years in previous work) and to construct better indicators of the technological content of a product (*e.g.* estimation of R&D stock), current R&D expenditures have been used to estimate the embodied R&D flows for a particular year. Nevertheless, the inclusion of these omitted points will be considered in the near future.

- *R&D embodied in the purchased domestic capital goods*

Similarly, the R&D embodied in capital equipment purchases by industry *j* from industry *i*, $RINV^{d}_{ij}$ can be shown as:

$$RINV^{d}_{ij} = INV^{d}_{ij} \frac{R_i}{X_i} \qquad (2)$$

where INV_{ij} is the sales of capital good from industry *i* to industry *j* in a particular year.

The rising trend of high-technology trade in the OECD exports and imports implies that domestic production has increasingly become dependent on advanced foreign technology so that R&D flows should be traced between countries. These R&D flows across a country's borders are calculated by distinguishing the sources of R&D by country of origin together as well as by types of products (intermediate goods and capital goods).

- *R&D embodied in purchased imported intermediate inputs*

For a particular country, the R&D embodied in imported intermediate inputs *i* purchased by industry *j* will be calculated by using:

$$RII^m_{ij} = X^m_{ij}(\sum_k \alpha_{ik} \cdot \frac{R_{ik}}{X_{ik}}) \quad (3)$$

where X^m_{ij} is the demand for imported intermediate input of product *i* by industry *j* and α_{ik} the import share of country *k*. This indicator can be also broken down by country of origin of R&D.

- *R&D embodied in purchased imported capital goods*

In a similar way, R&D embodied in imported capital goods purchased by industry *j* from abroad might be calculated by:

$$RINV^m_{ij} = INV^m_{ij} \sum_k \alpha_{ik} \cdot \frac{R_{ik}}{X_{ik}}) \quad (4)$$

- *Total R&D embodiment in industry*

Lastly, total R&D gains of industry *j* can be obtained by summing up these indirect R&D embodiment across sectors, plus own R&D expenditures conducted by industry *j* himself.

$$RT_j = R_j + \sum_{i \neq j} RII^d_{ij} + \sum_{i \neq j} RII^m_{ij} + \sum_{i \neq j} RINV^d_{ij} + \sum_{i \neq j} RINV^m_{ij} \quad (5)$$

In the above equation, the diagonal elements of each matrix are eliminated in order to avoid the double counting of own R&D with other R&D. The first term of this equation shows the amount of direct R&D and the other three terms describe the measures of indirect R&D embodied in the industry *j*'s purchase of either intermediate or capital goods domestically and from abroad. The intensity version of these indicators, R&D embodiment per unit of output, can be simply calculated by dividing each term of the above equation by the industry's output X_j. Other indicators such as the ratios of direct/indirect R&D or domestic/imported R&D have also been calculated.

Although it is not included in this preliminary study, the above technology flow matrix approach can be extended so as to incorporate interindustry ripple effects by considering the second round impact through intermediate flows among industries. The inclusion of such multiplier effects in the calculation of indirect R&D embodiment can be important. For example, semiconductor industry undertakes large-scale R&D. New models of automobiles or aerospace are increasingly using semiconductors for automatic engine control or advanced navigation systems. However, these sectors frequently do not purchase directly the semiconductor product; instead the semiconductor is contained in a part purchased from a supplier. The present model does not take into account the semiconductor R&D in these parts when calculating the indirect R&D used by the auto or aerospace sectors. Precise R&D contents of each products can be only estimated by using the Leontief inverse. The Leontief inverse approach will be presented in the next section.

b) Leontief inverse approach

The balance equations of gross output in an open static input-output system for domestic flows can be written as:

$$X = A^d X + S^d I + F^d + E \qquad (6)$$

where X is the vector of gross outputs, A^d is the matrix of domestic input-output coefficients, S^d is the share matrix of private business investment ($s^d_{ij} = I^d_{ij} / I_j$), I the vector of total private business investment by sector of origin, F^d final demand vectors of domestic output and imports exclusive of investment expenditures and E is exports vector. Investment expenditures are treated as exogenous in equations (6).

From domestic balance equations (6), we obtain:

$$X = (I - A^d)^{-1} [S^d I + F^d + E] \qquad (7)$$

Defining the sectoral direct R&D intensity as:

$$r_i = \frac{R_i}{X_i} \qquad (i = 1,2,\dots n) \qquad (8)$$

The vector of domestic total R&D embodiment, T^d, can be defined by pre-multiplying the diagonalised matrix of sectoral R&D coefficients (8) to equation (7), so that we obtain:

$$T^d = r(I - A^d)[S^d I + F^d + E] \qquad (9)$$

Equation (9) shows that total domestic R&D embodiment can be connected to each components of domestic final demand and exports. Based on equation (9), 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 above coefficients matrix:

$$rf_j = \sum_{i=1}^{n} r_i b_{ij} \qquad (j = 1,2,\dots, n) \qquad (10)$$

where b_{ij} are the elements of inverse $B = (I\text{-}A^d)^{-1}$. Since the *j*th column sum of the Leontief inverse B measures the total (direct and indirect) impacts on domestic production when final demand for the *j*th sector changes by unity, the right side of the equation (10) indicates the total R&D embodiment per unit of the final delivery of output *j*.

The calculation of total R&D embodiments in purchased intermediate goods for industry *j* is slightly different from the above equation (10), because it is based on final demand not on industry's output. In other words, it speaks about how much R&D is embodied in one unit of final demand for output *j*, not about how much R&D is embodied in output *j*. The industry's R&D embodiment needs to address the latter question. This modification will be done by using the following output-to-output based multiplier:

$$\begin{bmatrix} 1-a^d_{11} & -a^d_{12} & \dots & -a^d_{1,n-1} \\ -a^d_{21} & 1-a^d_{22} & \dots & -a^d_{2,n-1} \\ \vdots & \vdots & \vdots & \vdots \\ -a^d_{n-1,1} & -a^d_{n-1,2} & \dots & 1-a^d_{n-1,n-1} \end{bmatrix} \times \begin{bmatrix} a^d_{1,n} \\ a^d_{2,n} \\ \vdots \\ a^d_{n-1,n} \end{bmatrix} = \begin{bmatrix} \frac{b_{1,n}}{b_{n,n}} \\ \frac{b_{2,n}}{b_{n,n}} \\ \vdots \\ \frac{b_{n-1,n}}{b_{n,n}} \end{bmatrix} = B^*_n \tag{11}$$

The above adjusted multipliers indicates a vector of total output necessities from each sector except industry *j* to produce one unit of output for industry *n* (for convenience, suppose that industry $n = j$). We define thus adjusted multiplier matrix as $B^* = [B_1, B_2, ..., B_n]$.

Using the elements of B^*, total R&D embodied in domestic intermediate inputs for industry j can be obtained by pre-multiplying direct R&D intensity vector as:

$$rii^d{}_j = \sum_{i \neq j}^{n-1} r_{ij} \, b^*_{ij} \tag{12}$$

Other formulae of R&D embodiments, corresponding to equation (2) to (5) in the main text, will be defined in the following manner.

** R&D embodied in purchased domestic capital goods for industry j*

$$rinv^d{}_j = \sum_{i=1}^{n} r_i \Big(\sum_{k=1}^{n} b_{ik} \, s^d{}_{kj} \Big) \tag{13}$$

** R&D embodied in purchased imported intermediate inputs for industry j* (k indicates country)

$$rii^m{}_j = \sum_{i=1}^{n} a^{mij} \sum_{k=1}^{n} (\alpha_{ik} \; . \; rf^d{}_{ik}) \tag{14}$$

** R&D embodied in purchased imported capital goods for industry j* (k indicates country)

$$rinv^m{}_j = \sum_{i=1}^{n} s^{mij} \sum_{k=1}^{n} (\alpha_{ik} \; . \; tinv^d{}_{ik}) \tag{15}$$

** Total R&D Embodiment for industry j*

$$rt_j = r_j + rii^d{}_j + rinv^d{}_j + rii^m{}_j + rinv^m{}_j \tag{16}$$

ANNEX 2

Table 3. Classification of industries based on technology intensity

ISIC Rev. 2		1990 R&D production	1990 R&D value added	1990 dir+ind R& productio	1980 R&D production	1980 R&D value adde	1980
Aerospace	3845	17.30	14.98	36.25	16.06	14.13	41.11
Office & computing equipment	3825	14.37	11.46	30.49	11.19	9.00	26.01
Drugs & medicines	3522	11.35	10.47	21.57	8.37	7.62	16.89
Radio, TV & communication equipment	3832	9.40	8.03	18.65	9.33	8.35	18.43
Medium-high-technology industries							
Scientific instruments	385	6.55	5.10	11.19	4.69	3.61	8.63
Motor vehicles	3843	4.44	3.41	13.70	3.68	2.81	10.05
Electrical machines excl. commun. equip.	383 - 3832	3.96	2.81	7.63	4.25	3.48	8.85
Chemicals excl. drugs	351+352-3522	3.84	3.20	8.96	2.67	2.15	7.60
Other transport	3842+3844+3849	3.03	1.58	3.97	1.69	0.98	2.70
Non-electrical machinery	382 - 3825	2.58	1.74	4.58	2.00	1.32	3.48
Medium-low-technology industries							
Rubber & plastic products	355+356	2.47	1.07	3.02	2.20	1.08	3.27
Shipbuilding & repairing	3841	2.21	0.74	2.13	1.42	0.39	1.11
Other manufacturing	39	1.76	0.63	1.52	1.45	0.79	2.19
Non-ferrous metals	372	1.57	0.93	3.48	1.04	0.54	2.29
Non-metallic mineral products	36	1.44	0.93	2.20	1.10	0.66	1.72
Metal products	381	1.35	0.63	1.39	1.06	0.45	1.08
Petroleum refineries & products	353+354	1.33	0.96	8.43	0.80	0.58	6.17
Ferrous metals	371	1.10	0.64	2.48	0.78	0.45	1.71
Low-technology industries							
Paper, products & printing	34	0.88	0.31	0.76	0.68	0.23	0.61
Textiles, apparel & leather	32	0.78	0.23	0.65	0.56	0.13	0.38
Food, beverages & tobacco	31	0.73	0.34	1.14	0.56	0.23	0.93
Wood products & furniture	33	0.65	0.18	0.47	0.55	0.14	0.39

Source: OECD, ANBERD, STAN, Input-Output and BILAT databases (DSTI, EAS division).

Table 4. High Technology Products List - SITC Revision 3

(Period 1988 - 1995)

Group	Code SITC	Title
1-		**AEROSPACE**
	7921+7922+7923+7924+7925+79291+79293+(714 -71489-71499)+87411	
1-1.	7921-	Helicopters
1-2.	7922+7923+7924+792	Aeroplanes
	of which: 7922-	Aeroplanes of an unladen weight < 2000 kg
	7923-	Aeroplanes of an unladen weight > 2000 kg and < 15000 kg
	7924-	Aeroplanes of an unladen weight > 15000 kg
	7925-	Spacecraft (including satellites and launch vehicles)
1-3.	79291	Propellers, rotors and parts thereof
1-4.	79293	Under-carriages and parts thereof
1-5.	714 -71489-	Aeroplanes motors
	of which: 71441	Turbo-jets
	71449	Other than turbo-jets
	71481	Turbo-propellers
	71491	Parts of turbo-jets or turbo-propellers
1-6.	87411	Other navigational instruments
2-		**COMPUTERS - OFFICE MACHINES**
	75113+75131+75132+75134+(752-7529)+75997	
2-1.	75113	Word-processing machines
2-2.	75131+75132+7513	Photo-copying apparatus
2-3.	752 - 7529	Computers
	of which: 7521-	Analogue or hybrid data processing machines
	7522-	Digital automatic data processing with a central processing unit
	7523-	Digital automatic data processing with storage, input or output units
	7526-	Input or output units
	7527-	Storage units
2-4.	75997	Parts and accessories of group 752--
3-		**ELECTRONICS -TELECOMMUNICATIIONS**
	76381+76383+(764 - 76493 - 76499)+7722+77261+77318+77625+77627+7763 +7764+7768+89879	
3-1.	76381	Video apparatus
3-2.	76383	Other sound reproducing apparatus
3-3.	764--	Telecommunications equipment
3-3-1.	*of which:* 7641-	Electrical apparatus for telephone or telegraphe
	of which: 76411	Telephone sets
	76413	Teleprinters
	76415	Communication apparatus
	76417	Other apparatus for carrier-current line systems
	76419	Other telephonic apparatus, n.e.s.

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Group	Code SITC			Title
3-3-2.		7642-		Microphones, loudspeakers and amplifiers
3-3-2-1.		*of which:*	76421	Microphones
3-3-2-2.			76422+76423	Loudspeakers
			of which: 76422	Loudspeakers, mounted in their ensolures
			76423	Loudspeakers, not mounted in their ensolures
3-3-2-3.			76424	Headphones, earphones and combined microphone/speaker sets
3-3-2-4.			76425	Audio-frequency electric amplifiers
3-3-2-5.			76426	Other sound amplifiers
3-3-3.		7643-		Transmission apparatus for radio, telephone and TV, including reception apparatus
		of which:	76431	Transmission apparatus (without reception)
			76432	Transmission apparatus incorporating reception apparatus
3-3-4.		7648-		Telecommunications equipment, n.e.s.
		of which:	76481	Reception apparatus for radiotelephony
			76482	Television cameras
			76483	Radar apparatus
3-3-5.		76491		Parts and accessories of 7641-
3-3-6.		76492		Parts and accessories of 7642-
3-4.	7722-			Printed circuits
3-5.	77261			Electrical boards and consoles < 1000V
3-6.	77318			Optical fibre cables
3-7.	77625			Microwave tubes
3-8.	77627			Other valves and tubes
3-9.	7763-			Semi-conductor devices
	of which:	77631		Non-photosensitive diodes
		77632+77633		Transistors (excluding photosensitive transistors)
		77635		Thyristors, diacs and triacs
		77637		Photosensitive semi-conductor devices
		77639		Other semi-conductor devices
3-10.	7764-			Electronic integrated circuits and microassemblies
	of which:	77641		Digital monolithic integrated units
		77643		Non-digital monolithic integrated units
		77645		Hybrid integrated circuits
		77649		Other electronic integrated circuits
3-11.	7768-			Piezo-electric crystals
	of which:	77681		Piezo-electric crystals, mounted
		77688		Parts of the devices of 7763- and of 77681
		77689		Parts of the devices of 7764-
3-12.		89879		Numeric recording stays

4- **PHARMACY**

5413+5415+5416+5421+5422

4-1.	5413-		Antibiotics
	of which:	54131	Penicillins and their derivatives
		54132	Streptomycins and their derivatives
		54133	Tetracyclines and their derivatives
		54139	Other antibiotics
4-2.	5415-		Hormones and their derivatives
	of which:	54151	Insulin and its salts
		54152	Pituitary (anterior) or similar hormones

Group	Code SITC	Title
	54153	Adrenal cortical hormones
	54159	Other hormones and steroids
4-3.	5416-	Glycosides, glands, antisera, vaccines
	of which: 54161	Glycosides, natural or reproduced by synthesis
	54162	Glands and other organs, for organo-therapeutic uses
	54163	Antisera and other blood fractions, vaccines
	54164	Blood prepared for therapeutic uses
4-4.	5421-	Medicaments containing antibiotics or derivatives thereof
	of which: 54211	Containing penicillins and derivatives thereof, not put up in mesured doses for retail sale
	54212	Containing other penicillins, not put up in mesured doses for retail sale
	54213	Containing penicillins and derivatives thereof, put up in mesured doses for retail sale
	54219	Containing other penicillins, put up in mesured doses for retail sale
4-5.	5422-	Medicaments containing hormones or other products of heading 5415-
	of which: 54221	Containing insulin, not put up in mesured doses for retail sale
	54222	Containing other hormones or products, not put up in mesured doses for retail sale
	54223	Containing insulin, put up in mesured doses for retail sale
	54224	Containing adrenal cortex hormones, put up in mesured doses for retail sale
	54229	Containing other hormones of heading 5415-, put up in mesured doses for retail sale

5- SCIENTIFIC INSTRUMENTS

774+8711+8713+8714+8719+87211+(874 - 87411- 8742)+88111+88121+88411 +88419+89961+89963+89966+89967

Group	Code SITC	Title
5-1.	774--	Electro-diagnostic apparatus for medicine or surgery and radiological apparatus
5-1-1.	*of which:* 7741-	Electro-diagnostic apparatus (excepting radiological apparatus)
	of which: 77411	Electro-cardiographs
	77412	Other electro-diagnostic apparatus
	77413	Ultra-violet or infra-red ray apparatus
5-1-2.	7742-	Apparatus based on the use of x-rays or of alpha, beta or gamma radiations
	of which: 77421	Apparatus based on the use of x-rays (for medical uses)
	77422	Apparatus based on the use of alpha, beta or gamma radiations
	77423	X-ray tubes
	77429	Parts and accessories of 7742-
5-2.	8711-	Binoculars, astronomical instruments and optical telescopes
5-3.	8713-	Microscopes (other than optical microscopes)
	of which: 87131	Microscopes other than optical microscopes
	87139	Parts and accessories
5-4.	8714-	Compound optical microscopes
	of which: 87141	Stereoscopic microscopes
	87143	Other microscopes (including for microphotography)
	87145	Microscopes, n.e.s.
	87149	Parts and accessories
5-5.	8719-	Liquid crystal devices, lasers and other optical instruments
	of which: 87191	Telescopic sights for fitting to arms

Group	Code SITC		Title
	87192		Lasers
	87193		Other devices and instruments
	87199		Parts and accessories of 8719-
5-6.	87211		Dental drill engines
5-7.	874 - 87411- 8742		Measuring instruments and apparatus
5-7-1.	*of which:* 8741 - 87411		Compasses, navigational instruments, geodesic instruments
	of which:	87412	Parts and accessories
		87413	Geodesic instruments
		87414	Parts and accessories
5-7-2.	8743-		Instruments for measuring or checking the flow, level, pressure or other variables of liquids or gases
	of which:	87431	Instruments for measuring the flow or level of liquids
		87435	Instruments for checking pressure
		87437	Other instruments and apparatus
		87439	Parts and accessories of 8743-
5-7-3.	8744-		Instruments for physical or chemical analysis
	of which:	87441	Gaz or smoke analysis apparatus
		87442	Shromatographs
		87443	Spectrometers, spectrographs using optical radiations
		87444	Exposure meters
		87445	Other apparatus using optical radiations
		87446	Apparatus for physical or chemical analysis, n.e.s.
		87449	Parts and accessories of 8744-
5-7-4.	8745-		Measuring, controlling and scientific instruments, n.e.s.
	of which:	87451	Sensitive balances
		87452	Instruments designed for demonstrational purposes
		87453	Appliances for testing the hardness
		87454	Parts and accessories of 87453
		87455	Density meters
		87456	Parts and accessories of 87455
5-7-5.	8746-		Automatic regulating or controlling instruments
	of which:	87461	Thermostats
		87463	Pressure regulators
		87465	Other regulating or controlling apparatus
		87469	Parts and accessories of 8746-
5-7-6.	8747-		Oscilloscopes, spectrum analyzers
	of which:	87471	Instruments for detecting ionizing radiations
		87473	Cathode-ray oscilloscopes and cathode-ray oscillographes
		87475	Other instruments for checking voltage, current and resistance
		87477	Instruments designed for telecommunications
		87478	Other instruments for measuring electrical quantities
		87479	Parts and accessories of 8747-
5-7-7.	8749-		Parts and accessories, n.e.s.
5-8.	88111		Photographic cameras
5-9.	88121		Cinematographic cameras
5-10.	88411		Contact lenses
5-11.	88419		Optical fibres other than those of heading 7731-
5-12.	89961		Hearing aids
5-13.	89963		Orthopaedic appliances
5-14.	89966		Ocular prosthesis
5-15.	89967		Pacemakers for stimulating heart muscles

Group	Code SITC	Title
6-	***77862+77863+77864+77865+7787+77884***	**ELECTRICAL MACHINERY**
6-1.	77862+77863+77864+77865	Electrical fixed capacitors
	of which: 77862	Tantalum fixed capacitors
	77863	Aluminium electrolytic fixed capacitors
	77864	Ceramic dielectric fixed capacitors, single layer
	77865	Ceramic dielectric fixed capacitors, multilayer
6-2.	7787-	Electrical machines, having individual fonctions
	of which: 77871	Particle accelerators
	77878	Other machines, having individual fonctions
	77879	Parts and accessories of 7787-
6-3.	77884	Electric sound or visual signalling apparatus
7-	***52222+52223+52229+52269+525+531+57433+591***	**CHEMISTRY**
7-1.	52222+52223+52229+52269	Inorganic chemical elements
	of which: 52222	Selenium, tellurium, phosphorus,arsenic and boron
	52223	Silicon
	52229	Calcium, strontium and barium
	52269	Other inorganic bases
7-2.	525--	Radio-active materials
7-2-1.	*of which:* 5251-	Radio-active isotopes
	of which: 52511	Natural uranium and its compounds
	52513	Uranium enriched in U235, plutonium and its compounds
	52515	Uranium depleted in U235
	52517	Spent fuel elements of nuclear reactors
	52519	Radio-active isotopes, n.e.s.
7-2-2.	5259-	Stable isotopes and their compounds
	of which: 52591	Isotopes other than those of heading 5251-
	52595	Compounds, inorganic or organic, of rare-earth metals
7-3.	531--	Organic colouring matter and colour lakes
	of which: 5311-	Organic colouring matter
	5312-	Synthetic organic products of a kind used as flourescent brightening agents or luminophores
7-4.	57433	Polyethylene terephthalate
7-5.	591--	Insecticides, disinfectants
	of which: 5911-	Insecticides
	5912-	Fungicides
	5913-	Herbicides, anti-sprouting products
	5914-	Disinfectants

Group	Code SITC	Title
8-		**NON-ELECTRICAL MACHINERY**
	71489+71499+71871+71877+71878+72847+7311+73131+73135+73142+73144+73151+73153+73161+73163+73165+73312+73314+73316+7359+73733+73735	
8-1.	71489	Other gas turbines
8-2.	71499	Parts of gas turbines
8-3.	71871	Nuclear reactors
8-4.	71877	Fuel elements non-irradiated
8-5.	71878	Parts of nuclear reactors
8-6.	72847	Machinery and apparatus for isotopic separation
8-7.	7311-	Machine-tools working by laser or other light or photon beam, ultra-sonic, electro-discharge or electro-chemical processes
	of which: 73111	Operated by laser or other light or photon beam processes
	73112	Operated by ultra-sonic processes
	73113	Operated by electro-discharge processes
	73114	Operated by electro-chemical, electron beam, ionic-beam or plasma jet processes
8-8.	73131+73135+73142+73144+73151+73153+73161+73163+73165+73312+73314+73316+7359+73733+73735	Machine-tools, numerically controlled
8-8-1.	*of which:* 73131	Horizontal lathes, numerically controlled
8-8-2.	73135	Other lathes, numerically controlled
8-8-3.	73142	Other drilling machines, numerically controlled
8-8-4.	73144	Other boring-milling machines, numerically controlled
8-8-5.	73151	Milling machines, knee-type, numerically controlled
8-8-6.	73153	Other milling machines, numerically controlled
8-8-7.	73161	Plat-surface grinding machines, numerically controlled
8-8-8.	73163	Other grinding machines, numerically controlled
8-8-9.	73165	Sharpening machines, numerically controlled
8-8-10.	73312	Bending, folding, straightening or flattening machines, numerically controlled
8-8-11.	73314	Shearing machines, numerically controlled
8-8-12.	73316	Punching machines, numerically controlled
8-8-13.	7359-	Parts and accessories of 731-- and 733--
	of which: 73591	Parts and accessories of 731--
	73595	Parts and accessories of 733--
8-8-14.	73733	Machines and apparatus for resistance welding of metal, fully or partly automatic
8-8-15.	73735	Machines and apparatus for arc, including plasma arc welding of metal, fully or partly automatic
9-	**891--**	**ARMAMENT**
9-1.	8911-	Armoured fighting vehicles
9-2.	8912-	Bombs, torpedoes, mines,missiles, etc...
9-3.	8913-	Non-military arms
9-4.	8919-	Parts and accessories of 89112, 89114 and 8913-

NOTES

1. “International Trade in High Research and Development-Intensive Products” [SITC/80.48]. “International Trade in High Technology Products: An Empirical Approach” (internal OECD memorandum).

2. “Specialisation and Competitiveness in High, Medium and Low R&D-Intensity Manufacturing Industries: General Trends” (internal OECD memorandum).

3. The R&D data employed come from the OECD’s *Analytical Business Enterprise Research and Development (ANBERD) Database*. This is an estimated database constructed with the objective of creating a consistent data set that overcomes the problems of international comparability and time discontinuity associated with the official business enterprise R&D data provided to the OECD by its Member countries. ANBERD contains R&D expenditures for the period 1973 to 1995, by industry, for 15 OECD countries.

4. Sectors for which complete data were to hand, and countries for which harmonized input-output tables are available: the United States, Japan, Germany, France, the United Kingdom, Italy, Canada, Australia, the Netherlands and Denmark.

5. However, it must be acknowledged that, even at product level, the classifications are not sufficiently detailed for products which have the same name, but belong to very different ranges, to be put into separate categories.

6. For this purpose we used the concordance between SITC Rev. 3 (product classification) and ISIC Rev. 2 (sectoral classification).

7. The OECD’s *Input-Output Database* contains flow matrices of intermediate and final goods (both domestic and imported) for selected years in the 1970-90 period. It covers 10 OECD countries and 36 industries, of which 22 are in the manufacturing sector.

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