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EMBODIED TECHNOLOGICAL DIFFUSION: AN EMPIRICAL ANALYSIS FOR 10 OECD COUNTRIES

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Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries

George Papaconstantinou*, Norihisa Sakurai**, Andrew Wyckoff ***

This paper examines the process of embodied technology diffusion in 10 OECD countries with the help of a methodology whereby the purchases of intermediate and capital goods act as carriers of technology across industries and countries. In terms of supply and demand of technology, it establishes that while innovations are developed mainly in a cluster of high technology manufacturing industries, a different cluster of industries in the services sector are the main acquirers of technologically sophisticated machinery and equipment. R&D performance is more concentrated (the top 5 industries account for between 60-80% of total) than technology use (the top 5 user industries account in most countries for 40-50% of total). In terms of the channels of technology diffusion, the share of technology obtained through capital investment is less than 50% of total acquired technology for every country, with the US leading in the diffusion of technology through capital investment. Imports are also an important method of technology acquisition: the share of acquired technology through imports has increased over time for all countries except Japan, while in intensity terms, imported technology is more important than domestic technology for all countries except the US, Germany and Japan. Bigger countries source less technology from abroad than smaller countries which depend on imports for more than 50% of their acquired technology. The US is the most important source of technology for all countries. Finally, the information technology cluster of industries is the main source of technology acquired in most countries. The importance of IT has increased over time; it is the fastest growing acquired technology cluster, with the share of other technology clusters is steady or declining.

At the time of preparation of this paper, all authors were at the Economic Analysis and Statistics Division of the Directorate for Science, Technology and Industry, OECD. Opinions expressed in the paper are personal and do not engage the OECD and its Member countries, or the Central Research Institute of the Electric Power Industry in Japan.

Ce document examine le processus de diffusion de la technologie incorporée dans 10 pays de l'OCDE, à l'aide d'une méthode voulant que les achats de biens intermédiaires et de biens d'équipement constituent le vecteur des transferts de technologies entre branches et entre pays. Sur le plan de l'offre et de la demande de technologie, il en résulte que les innovations sont le fait principalement d'un groupe d'industries manufacturières de haute technologie, et que les principaux acquéreurs de machines et équipements technologiquement complexes appartiennent à un autre groupe d'industries, du secteur des services. La production de R-D est donc plus concentrée (le quintile supérieur représentant 60 à 80 % du total) que l'utilisation des technologies (dont 40 à 50 % sont imputables aux 5 premières industries utilisatrices dans la plupart des pays). Pour ce qui est des canaux de diffusion, moins de 50 % des technologies acquises dans chaque pays proviennent d'un investissement en capital, les Etats-Unis étant le pays où ce mode de diffusion est le plus fréquent. Les importations jouent, elles aussi, un rôle important dans l'acquisition des technologies : la part des technologies acquises grâce aux importations s'est accrue au fil du temps dans tous les pays, à l'exception du Japon, et les technologies importées interviennent davantage dans le niveau d'intensité technologique que les technologies d'origine intérieure, dans tous les pays à l'exception des Etats-Unis, de l'Allemagne et du Japon. Les grands pays sont moins tributaires de l'étranger que les petits qui acquièrent plus de 50 % de leurs technologies grâce à l'importation. Dans tous les pays, la plus grosse part des technologies acquises vient des Etats-Unis. Enfin, les industries des technologies de l'information constituent la principale source de technologies acquises dans la plupart des pays. L'importance des TI s'est accrue avec le temps ; c'est la catégorie de technologies acquises qui affiche la croissance la plus rapide, la part des autres catégories de technologies étant stationnaire ou en déclin.

Lorsque ce document a été rédigé, tous les auteurs étaient membres de la Division des analyses économiques et des statistiques de la Direction de la science, de la technologie et de l'industrie de l'OCDE. Les opinions exprimées dans ce document sont celles des auteurs et n'engagent ni l'OCDE, ni ses pays Membres, ni l'Institut central de recherche de l'industrie électrique du Japon.

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SUMMARY

This paper examines the process of embodied technology diffusion in 10 OECD countries with the help of a methodology whereby the purchases of intermediate and capital goods act as carriers of technology across industries and countries. A number of issues are examined: the patterns of supply and demand of technology; the adequacy of existing indicators of technological level of industries for guiding policy; the role of capital equipment purchases in technology diffusion; the importance of imported technology; and the role of technology clusters, especially that of information technologies. The main results of the analysis are:

Supply and demand of technology. Innovations are developed mainly in a cluster of high technology manufacturing industries; a different cluster of industries in the services sector are the main acquirers of technologically sophisticated machinery and equipment. R&D performance is more concentrated (the top 5 industries account for between 60-80% of total) than technology use (the top 5 user industries account in most countries for 40-50% of total). The use of technology in many service industries is higher than what their (large) weight in the economy might suggest. The part of total technology embodied in output which is acquired externally has increased over time, either because of more extensive sourcing of high technology goods or because of changes in the strategies of firms (more subcontracting).

Reinterpreting technology intensity. Simple R&D intensity indicators are a misleading measure of technological sophistication of industries; indicators combining both performed R&D and externally acquired technology at the sectoral level are more appropriate. The distinction between high, medium and low technology industries blurs when accounting for the purchase of technologically sophisticated inputs. The technology intensity of small countries increases significantly with acquired technology; big increases can also be seen in the technology intensity of medium technology industries in Japan, Germany, Canada, Netherlands; the total technology intensity for Japan overtakes that of the US..

The role of capital inputs in technology diffusion. The share of technology obtained through capital investment is less than 50% of total acquired technology for every country (but this is probably an underestimate); the US leads in the diffusion of technology through capital investment. The industries most depended on investment-based technology acquisition are finance and insurance, social and personal, and communication services; those least dependent are the high technology manufacturing industries.

Technology acquisition through imports. Bigger countries source less technology from abroad than smaller countries which depend on imports for more than 50% of their acquired technology; the share of acquired technology through imports has increased over time for all countries except Japan. In intensity terms, imported technology is more important than domestic technology for all countries except the US, Germany and Japan. The US is the most important source of technology for all countries; for the US, the DAEs and Japan are the most important source of technology acquired through imports.

Technology clusters. The information technology cluster of industries is the main source of technology acquired in 6 out of 10 countries; the materials technology cluster (chemicals, basic metals,

rubber, plastics) is important in Japan, Germany, Italy, Denmark. The importance of IT has increased over time; it is the fastest growing acquired technology cluster; the share of other technology clusters is steady or declining. Different technologies tend to gravitate to different sectors: IT to high-tech manufacturing, communications and business services; transportation technology to transportation services; consumers goods technology to wholesale and retail trade; materials technology to agriculture, and to MT and LT manufacturing; and fabrication technology to mining, utilities, construction.

I. Introduction

Aim and scope of the paper

The capacity to innovate successfully and to realise the economic potential of new technologies is one of the main sources of economic growth. The development of new processes and products and their diffusion across firms, industries, and countries lead to increases in productivity, initially in the firms and industries developing the new technologies, and eventually economy-wide. These productivity gains displace jobs in certain industries; lower prices and higher profits however are translated to higher incomes and economic growth. (OECD 1994d, 1994e).

The capacity to innovate depends on a multitude of factors, including the skill level of the work force, the "learning" ability of firms and the general environment within which firms operate. Of these, research and development (R&D) expenditures are critical, and their level helps determine both productivity gains and success in international markets. New technologies are developed in the relatively small number of sectors that invest heavily in R&D activities.

Yet it is less the invention of new products and processes and their initial commercial exploitation that generate major economic benefits than their widespread diffusion and use. The economic performance of most manufacturing and service industries depends on putting technology to work by adopting and using ideas and products developed elsewhere. The ability of firms to translate innovations into new products and processes and the timely and widespread diffusion of technologies is critical.

Despite its importance, the process of technology diffusion is still imperfectly understood, and technology policy continues to focus mainly on encouraging innovation. This paper analyses technology diffusion across industrial sectors and national frontiers in 10 OECD countries. It attempts to identify the industries in which technology originates and the industries which benefit most or least from the flows of technology embodied in new products; the technological content of a given industry's or country's investment; the role of technology imports; and clusters of industries which share technology.

There are a number of policy concerns directly related to these analytical issues. The first relates to the balance between innovation and diffusion policies. While more and more countries emphasise policy measures that remove obstacles and facilitate the diffusion process, technology policy continues to focus overwhelmingly on encouraging the development of new processes and products in a limited number of "high technology" industries. This often involves a cost: reliance on the strength of a few high-technology manufacturing industries is not likely to deliver economy-wide productivity gains from new technologies.

Another policy issue concerns the importance, for realising the social returns to innovative activity, of competitive pressures on industries that supply new technologies (Griliches, 1979; Stoneman and Diederen, 1994). Monopoly structures in the industries that develop new technologies allow them to charge prices which appropriate most of the benefits of innovation. As a result, productivity gains in user industries are lower than they would be if supplier markets were more competitive. Policies in this respect need to strike a balance: ensuring both that firms have sufficient incentives to innovate (through intellectual property rights) and that they cannot capture all the benefits from their innovations.

A number of policy issues also follow directly from the positive externalities involved in generating and diffusing technology, owing to the "network" characteristics of many new technologies, whose benefits depend on the number of users (fax machines, for example). In this regard, the role of governments is to encourage networks and learning among firms and industries and to support international collaborative agreements regarding technology and the setting of standards.

Finally, there is the importance of an open trade regime for realising the economic potential of new technologies. It is becoming increasingly clear that industrial globalisation and the international sourcing of technology increase the costs of trade protection. In addition to consumers' traditional welfare costs, producers who are sourcing technologically advanced equipment and components from abroad suffer substantial costs as well. To the extent that it is important to have access to and to be able to adopt and adapt technologies developed elsewhere in order to innovate, the economy as a whole pays a more general cost from protection in terms of a slower rate of technological development.

Some concepts

Technology diffusion refers to all the mechanisms through which firms acquire technology externally rather than generating it internally. Broadly speaking, it consists of two types: "disembodied" diffusion and equipment-embodied diffusion. Disembodied diffusion is the transmission of knowledge, technical expertise, or technology in a way that does not necessarily involve the purchase of machinery and equipment incorporating new technology. This is sometimes an organised process: firms may, for example, sell the rights to a patent or licence an innovation. More often, however, it is simply a consequence of innovative activity: the knowledge that the firm develops becomes available to others.[1]

Two central notions help explain both the pattern and the determinants of disembodied technology diffusion. The first is *research spillovers*.[2] These are the means by which new knowledge or new technology developed by one firm become potentially available to other firms or industries, domestically or abroad. Spillovers arise because knowledge has some of the properties of public goods, in that its economic benefits cannot be entirely appropriated by the firm that develops it.

The second central notion is that of *absorptive capacity*. While spillovers determine the potential flows of disembodied diffusion, it is the efforts of the receiving firms and industries themselves that determine to what extent innovations developed elsewhere are actually incorporated into production processes. Thus, a firm's R&D expenditures and other intangible investments not only generate innovations, they also enhance its ability to assimilate and exploit information in the public domain (Cohen and Levinthal, 1989; OECD, 1992). Absorptive capacity is also important in the context of embodied technology diffusion.

It should be noted that certain aspects of innovation dilute to some degree its public good characteristics and make substantive investments that will favour absorption a prerequisite for diffusion. Most technical advances today build on previous technology and incorporate many of the features of the displaced products and processes, so that the probability of successful innovation is a function of previously achieved results: what firms will do in the future is strongly conditioned by what they have done in the past (Stiglitz, 1987; Arthur, 1988). Thus, spillovers lead to high levels of intangible investment: the demand for new technology (the diffusion process) acts as a spur for supply (the innovation process); innovation and diffusion are in other words complements, not substitutes.

Equipment-embodied diffusion is the introduction into production processes of machinery, equipment and components which incorporate new technology. It recalls the more familiar pattern in which a cluster of industries supplies new technology. These industries are mainly (though not exclusively, with the service sector increasingly undertaking R&D of its own) in the R&D-intensive manufacturing sector and include computers, aerospace, electrical machinery, parts of electronic appliances and communications equipment, drugs and medicines, and the scientific and chemicals industries. They sell their technologically intensive intermediate and capital goods to downstream industries (both manufacturing and non-manufacturing), to consumers, and to government, all of which represent user demand for technologically intensive machinery, equipment, and components.

The mechanism through which equipment-embodied technology developed in one industry spreads and affects other industries involves a different kind of "spillover" (Griliches, 1979). While the knowledge spillover discussed above concerns externalities related to knowledge, the "spillover" relates here to the prices that user industries pay for their R&D-intensive inputs or that consumers pay for R&D-intensive products. Because of competitive pressures in the supplier industries, prices do not accurately reflect changes in the user value, or marginal productivity, or quality, of the new commodities. As a result, the buyer industry can capture part of the fruits of another's R&D efforts, and its productivity can be increased thanks to the R&D expenditures of the industries that supply it with intermediate (and capital) inputs.

The size and effect of this second type of spillover and the impact of equipment-embodied diffusion on the productivity of user firms and industries are determined by the market structure of the supplying industries. If the innovation-supplying industries are concentrated and exhibit strong monopolistic tendencies, they will be able to charge high prices for their technology and thus capture most of its social benefit. Competitive pressures will, on the other hand, force down prices, so that the purchase price of inputs will not fully reflect their increased downstream value; in this case, users will receive most of the benefit (Griliches, 1979; Mohnen, 1989).

The distinction between disembodied and embodied technology diffusion is clear conceptually, but much less so in practice. Empirical work attempting to measure technology flows across industries and countries has used different methodologies. Depending on the methodology used, the measurement will capture primarily either disembodied flows or embodied flows. Thus, work on interindustry flows through patents (see below) is closer to modelling disembodied diffusion flows; work using interindustry transactions flows based on input-output data is closer to embodied diffusion. Yet in practice, in both cases, the measure of total technology level or intensity of a particular industry will reflect both embodied and disembodied diffusion. This is because as noted above R&D investments have in effect a dual role: in addition to developing new products and processes, they are also aimed at helping firms absorb and assimilate technology developed elsewhere (Cohen and Levinthal, 1989).

II. Empirical studies of technology diffusion

Measuring spillovers and technology diffusion

The importance of technology diffusion and externalities (spillovers) in the innovation process has long been recognised. Early studies attempted to measure the difference between the economic returns from technology diffusion and those from technology development by quantifying the gap between private and social rates of return to innovation, but they did not explicitly identify the interindustry or intraindustry channels through which technology diffusion takes place. They concluded that the social returns from R&D (and especially from basic research) are significant and higher than private returns (Mansfield *et al.*, 1977, 1985; Bresnahan, 1986).

Subsequent empirical work explicitly modelled the channels of transmission of spillovers by constructing measures of technology flows or introducing an outside stock of knowledge as an input into the production process alongside a firm's (or industry's) own accumulated R&D stock or expenditures. A number of different methodological approaches have been used: *i)* surveys of the diffusion of new plant and equipment; *ii)* use of patent data to estimate technology flows and measure their impact on productivity; and *iii)* construction of technology flows through the use of input-output transactions matrices.

Technology surveys

Surveys of the use of new technologies, such as robots, numerically controlled machine tools, advanced materials, and microelectronics, have been undertaken in a number of countries. They measure actual adoption rates and provide a snapshot of the use of specific technologies throughout industry. One of the best known studies, done in the UK (Robson *et al.*, 1988), reveals that five "core" manufacturing sectors -- chemicals, machinery, mechanical engineering, instruments, and electronics -- account for about 65 per cent of all innovations. Innovations produced in these sectors are particularly pervasive, and are used in a large number of other sectors. Out of 26 user sectors, innovations originating in chemicals and electronics found applications in 18, mechanical engineering in 25, and instruments in 26.

Recent work on the diffusion of computer-based automation equipment in manufacturing in different OECD countries (OECD, 1989, 1990) reveals similar patterns and also underscores the importance of skills and firm organisation for the diffusion of advanced manufacturing technology. Essentially, firms must have management and technological competence and a broad range of skills of the appropriate kind and mix if applications are to be successful. Their relations with technology suppliers, the effects of links between large and small firms, and the strength or weakness of the technological infrastructure are all important factors in determining absorptive capacity.

Technology surveys have a number of limitations. They are by definition selective, focusing on the application of particular technologies in a given set of industries. Often, it is not possible to identify the source (industry and country) of the technology, so that while information on adoption rates is available, information on flows is not. Finally, most surveys have only dealt with the use of new technologies by manufacturing industries, yet the large share of services output and employment in GDP suggests that the technological sophistication of services is likely to be crucial to productivity growth and employment.

Technology flows based on patent data and innovation survey

Technology flow matrices based on patent data emphasise the role of patents as "carriers" of underlying R&D expenditures. Schmookler (1966) was among the first to express the view that improvements in performance associated with technological progress can result either from intramural R&D or from R&D performed in other firms/industrial sectors and embodied in ideas or goods purchased by an industry. He proposed a method for measuring the transmission of R&D-generated knowledge from R&D-performing industries to industries purchasing their products.

Scherer (1982a, 1982b, 1982c) extended this work by constructing an "interindustry technology flows" matrix along the lines suggested by Schmookler. Rather than relying exclusively on patents, he combined patent and R&D data in order to overcome the limitations of patents as cross-sectoral measures of industrial effort, which are due to the fact that the propensity to patent varies from one industry to another. In his scheme, patents are seen as carriers of underlying R&D expenditures, rather than as units of invention in their own right. Relying on Line of Business Data for US manufacturing firms, which make it possible to match industrial invention patents with the R&D expenditures for the activities that led to the inventions, he coded each patent in his sample according to industry of origin and industries of anticipated use of the patent. At the conclusion of this procedure, he "tagged" each patent with the average R&D expenditures per patent in the appropriate line of business category. The result was a matrix of technology flows for which both patents and R&D expenditures are classified according to industries of origin and (anticipated) use.

In related work, Evenson and Putnam (1988) constructed a patent concordance matrix for Canada based on Canadian Patent Office data (the Yale-Canada Concordance). They constructed a matrix of technology flows by computing the proportion of patented inventions originating in one industry but used in other industries, with the help of a concordance between industry classes and patent classes.[3] They compared US data on interindustry flows of technology (based on patent data) for a single year with the results of the innovation survey carried out by SPRU for the UK and concluded that the two countries' sectoral patterns of technology production were broadly similar. More than 97 per cent originated in manufacturing, with about two-thirds from the core groups, one-fifth from the secondary groups, and one-tenth from other manufacturing. The pattern of use of innovations, however, was somewhat different, with non-manufacturing sectors being much greater users of such technology in the US than in the UK.

Patent concordance matrices reveal something about the potential relevance of one industry's R&D activity to other industries. Since industries' R&D expenditures are heterogeneous, patent classifications according to industry of origin and use can help identify potentially significant R&D flows. However, they have disadvantages. They cannot reveal actual intersectoral spillovers if these are embodied in improved products that are traded across sectors. In practice, the construction of technology flow matrices like Scherer's, which are based on combined patent and R&D data, is very resource-intensive, while using the matrix constructed for Canada to analyse technology flows between industrial sectors in other countries is open to the criticism that the propensity to patent varies across countries, as well as across sectors.

Patents are only one innovation "output" indicator which can be used for the construction of technology flows. The use of innovation counts from surveys of innovative activities is another. DeBresson *et al.* (1994) have constructed a 43 x 66 innovation supplier-user matrix for Italy based on an innovation survey of 30 000 manufacturing business units for the period 1981-85. They found that Italian innovative activity was clustered in certain areas of economic activity and that it was more oriented towards final consumer goods than capital goods or other producer goods (in the chemical, metal products, mechanical machinery, and automobile industries). Consumers were by far the main users of innovation developed elsewhere, followed by the construction and automobile industries.

Technology flows on the basis of input-output matrices

An alternative method of constructing interindustry technology flows is to use input-output matrices combined with R&D expenditures. Input-output matrices make it possible to describe the economy on the basis of transactions across sectors for intermediate and investment goods. The usefulness of this methodology for mapping technology flows was originally suggested by Terleckyj (1974), and it has subsequently been employed in various papers and reports. It is the methodology adopted here, and it is developed in the following sections as a means of measuring the flows of embodied R&D and of constructing new indicators of technological intensity in individual industrial sectors.[4]

The main advantage of input-output matrices is that they reflect actual interindustry transactions. The method used to calculate technology flows then consists of using the input-output coefficients (*i.e.* each industrial sector's purchases, per unit of output, of intermediate and investment goods from other sectors) as weights for the R&D flows from a given sector to the sectors that purchase its products. In this way, purchased inputs (both of intermediate and of investment goods, domestic as well as foreign) act as carriers of technology across industrial sectors and from one country to others. Another advantage is that this methodology simultaneously takes into account both supply and demand factors and thereby goes beyond the "technology-push" and "demand-pull" debate (DeBresson, 1990; DeBresson *et al.*, 1994). Using this methodology, a study done for the US Department of Commerce (Davis, 1982, 1988), which focused on intersectoral and international technology flows between the US, Canada, and Japan, reinforced the widespread perception of the central role of certain key technologies (mostly IT-related) but also showed substantial international differences in the adoption of technologically sophisticated equipment.

The study stressed the fact that indirect technology inputs embodied in intermediate and capital inputs account for a large share of all technology embodied in total output (whether exported or for domestic use). Moreover, the relative importance of direct (innovation-based) to indirect (diffusion-based) technology inputs differs widely among countries. In 1984, for example, (domestic) indirect technology inputs averaged about three-fourths the direct inputs in Japan, but about 50 per cent in the US. This suggests that Japanese industries are both more dependent on technology from key indirect technology sources and more able to diffuse technology across industrial sectors. Canada, instead, was shown to be largely dependent on technology embodied in imports of intermediate and capital goods.

A recent Finnish study (Virtaharju and Akerblom, 1993), employing a similar methodology, divided Finnish industries into two groups: technology producers, characterised by extensive R&D and a small share of indirect technology; and buyers of technology, whose principal sources of technology were intermediate and capital inputs. The most technologically self-sufficient industries were the pharmaceuticals and telecommunications equipment sectors. Processing industries, food, textiles and clothing, and metal products relied most on acquired technology. One-fifth of total technology was embodied in imports, a share which declined in the 1980s as imports of intermediate goods dropped.

While input-output matrices provide a powerful tool for tracing technology flows across industrial sectors, they do have a number of disadvantages. First, the output of each supplier industry is assumed to be homogeneous, although there may be significant differences in the amounts of underlying R&D in different products. Second, all of the supplier industry's own R&D is assumed to be embodied in its output. In practice, however, only product R&D is embodied in output; process R&D manifests itself only in lower purchase prices and/or improved supplier profits. Third, the technology developed in one industry may affect other industries in the absence of transactions in intermediate or investment goods.

The methodology used in this page

Technology flows are estimated by using business enterprise R&D expenditures data with input-output and investment flows data to generate indicators of how industries use different types of inputs (intermediate inputs and investment goods) where "technology" is proxied by the R&D embodied in these inputs. This approach allows the separation of the equipment-embodied technology used by a particular industry into that which is generated by the industry itself and that which is acquired through purchases of intermediate inputs and investment goods (see Figure 1). Acquired technology is separated further into that portion which was obtained from domestic as opposed to foreign suppliers. Similarly, these acquired technology flows can be grouped into broad categories such as information technology, transportation equipment, consumer goods, materials, and fabrication equipment.

Estimation of technology flows

The methodology used for the estimation of technology flows between industries and across countries builds on a large body of literature[5]. It rests on two assumptions: R&D expenditures are used as a proxy for technology; and interindustry transactions are assumed to be the carriers of technology across industries and countries. Industries purchase intermediate and investment goods as inputs into their production processes. These intermediate and investment goods embody the technology (the R&D expenditures) of the industries where they originate. Thus technology is assumed to flow from one industry to another when the industry where R&D originates sells products which embody R&D to other industries to be used as inputs into their production processes. In other words, the output of a particular supplier industry is sold to various purchasing industries and these purchasing weights are used to allocate the producer's R&D across the user industries.

Thus, the technology embodied in the output of a certain industry is the sum of its own R&D expenditures and of that which is embodied in its purchases from other industries (of intermediate and investment goods, domestically or from abroad).[6] [See the Appendix for a full mathematical derivation.] More specifically, the methodology used in this paper models technology diffusion and acquisition through four separate channels of commodity transactions:

- purchases of domestic *intermediate* products;
- purchases of domestic *investment* inputs;
- purchases of *imported* intermediate products; and
- purchases of *imported investment* inputs.

The analysis can be conducted either by using technology *flows* or by normalising these to technology *intensities* (flows per unit of output). The *total technology intensity* of an industry *j* (defined as tti_j) is then the simple sum of five components: $tti_j = r_j + tint^d_j + tinv^d_j + tint^m_j + tinv^m_j$, where:

- r_j $(=R_j/X_j)$ is industry *j*'s own R&D intensity;
- $tint^d_j$ $(=TINT^d_j/X_j)$ is the R&D embodied in domestic intermediate inputs per unit of output of *j*;
- $tinv^d_j$ $(=TINV^d_j/X_j)$ is the R&D embodied in domestic investment inputs per unit of output of *j*;
- $tint^m_j$ $(=TINT^m_j/X_j)$ is the R&D embodied in imported intermediate inputs per unit of output of *j*;
- $tinv^m_j$ $(=TINV^m_j/X_j)$ is the R&D embodied in imported investment inputs per unit of output of *j*.

Of the four embodied R&D components, the R&D embodied in domestic intermediate input purchases $tint^d_j$ is the weighted sum of the R&D intensities of the industries from which industry *j* is purchasing inputs, with as weights the total (ie direct and indirect) domestic intermediate input requirements from each industry per unit of output of industry *j* obtained from a modified version of the Leontief inverse matrix.[7] The R&D embodied in domestic investment input purchases $tinv^d_j$ is the weighted sum of the same R&D intensities, with as weights industry *j*'s investment purchases from other industries multiplied by the total input requirements per unit of final demand of industry *j*.

Compared with domestic R&D flows, the formulation of imported R&D is rather simple, in the sense that it does not take into account the interindustrial propagation effects (which are captured through the Leontief inverse). Of the two embodied R&D components that relate to imported R&D, the R&D embodied in imported intermediate input purchases $tint^m_j$ is a weighted sum of foreign sectoral R&D intensities, with the weights being the intermediate demand of industry *j* from each other industry multiplied by the import share of that industry by trading partner country[8]. Similarly, the R&D embodied per unit of imported investment input purchases $tint^m_j$ is defined analogously as the weighted sum of foreign sectoral R&D intensities, with the weights being the investment demand of industry *j* from each other industry multiplied by the import share of that industry by trading partner country.

Strengths and weaknesses of the methodology

The main strength of the methodology is that it is rooted in comprehensive, economy-wide data and thus avoids the limitations associated with case studies. This is by virtue of the use of input-output relationships, which describe the economy as in interconnected system of industries. Unlike other studies of this type, the study will look at the variation which exists below the broad aggregate of manufacturing and include service sectors. The ability to look at service sectors is particularly important given the fact that technology is chiefly developed in manufacturing but is increasingly diffused in services, which account for two-thirds of total employment.

A second strength is that the methodology used is based on a well-established body of literature attempting to measure technology flows and link them to productivity growth and employment. The value-added of this paper is that it extends this methodology to distinguish between four different channels of technology diffusion and acquisition: (i) purchases of domestic *intermediate* products; (ii) purchases of domestic *investment* inputs; (iii) purchases of *imported* intermediate products and (iv) purchases of *imported investment* inputs.

Finally, another strength is the use of a data set which combines a high degree of international comparability across a wide cross-section of countries with the ability to match technology variables (R&D), industrial variables, inter-industry relationships (input-output matrices) and international trade flows. All other such studies are restricted to two or three country comparisons.

In terms of weaknesses, the methodology captures the flow of technology across sectors through the purchases of intermediate and capital inputs; yet in the presence of disembodied spillovers the R&D performed in one industry can benefit others even without any transactions taking place. This does not necessarily imply that only embodied technology diffusion is accounted for in the methodology; much recent theoretical and empirical work has argued that at least part of an industry's own R&D is aimed at assimilating the results of R&D done elsewhere. To the extent that in this methodology the measure of an industry's total technology level or intensity combines its own R&D with the technology acquired through input purchases from other sectors, it covers at least partly both embodied and disembodied technology diffusion, even if it cannot distinguish between the two.

The methodology also uses a number of limiting assumptions, common to much of the empirical work in this area. There are first the assumptions of static input-output analysis: constant returns to scale, capital investment exogenous to the model, and homogeneity of products within industries.[9] In particular the exogenous treatment of capital may underestimate the impact of R&D embodied in investment goods to the total R&D intensity of a sector and to its productivity growth.

In addition, an "import proportionality" assumption is used for the intermediate and investment flows matrices, namely that an imported input is proportionately distributed across all using industries (for example, if 10 per cent of total demand for steel is imported, and if both the motor vehicles and construction industries use steel, it is assumed that imported steel accounts for 10 per cent of their inputs). This assumption was also used in order to separate inputs by country of origin; thus, if 40 per cent of steel imports of country *a* come from country *b*, that share is assumed to hold for all industries in country *a* using imported steel. These assumptions are dictated by data availability; their impact is lessened to the extent that import matrices for many countries have been compiled on the basis of highly disaggregated data before being collapsed to the 36 industries used in this study.

There are finally a number of assumptions which relate to the specific methodology used for the estimation of technology flows. The first relates to the use of R&D intensities, as opposed to R&D stocks, as a measure of R&D activity and of the technology embodied in output. While calculation of R&D stocks may be preferable in principle, in practice lack of detailed information at the sectoral level on rates of obsolescence of R&D capital and on the lag structure that connects past R&D expenditures to current increases in technological knowledge make such calculations unreliable and render the alternative of using R&D intensity measures more attractive. Furthermore, in the productivity and technology estimations, an equivalence can be established between the use of intensities and using the rate of growth of R&D capital.

Another issue in this respect is the differential treatment in the method employed of R&D of domestic vs. imported embodied R&D. In calculating the R&D embodied in (intermediate and capital) imports, no attempt is made to account for the interindustry propagation effects in acquired R&D through the Leontief inverse matrix. This may underestimate the importance of the contribution of imported R&D. A satisfactory treatment of these indirect effects, however, would necessitate a "linked" input-output model solved simultaneously for a number of OECD countries.

III. The patterns of technology diffusion

This section of the paper analyses the patterns of embodied technology diffusion in 10 OECD countries on the basis of the methodology described above. It begins by addressing the question of who does R&D and who receives it -- identifying the industries that are the main R&D performers and those that use embodied technology as production inputs. The discussion then moves on to the implications of technology diffusion for defining the technology intensity of industries. It is argued that a more appropriate definition should take into account not only how R&D-intensive the production of a particular sector is, but also the level of technological sophistication of its intermediate inputs.

The methodology employed here makes it possible to distinguish between different means of technology diffusion and patterns of technology propagation across sectors and countries. This makes it possible, first, to examine the role of capital inputs in technology diffusion. The next issue addressed is international technology transfer; industries use imported inputs in their production processes, and these imports embody the R&D expenditures of the performing industry in the source country. The pattern of imported inputs thus provides information about the importance and sources of imported technology. Finally, this section investigates technology clusters, which are groups of industries sharing R&D, and examines how they differ in different countries.

Performed R&D and acquired technology

R&D expenditures and estimated embodied technology

All OECD countries invest significant funds into research and development activities. The level and rates of growth of R&D expenditures are widely seen as indicators of innovative capacity and as important determinants of productivity gains. These R&D expenditures mainly originate in manufacturing and are particularly concentrated in a few "high-technology" manufacturing industries (see below) such as computers, semiconductors or aerospace. The products of these industries which are developed with the help of R&D are sold to other sectors and are used as inputs into their production process or are sold directly to final demand for domestic consumption or exports. In this process, the R&D expenditures of the upstream industries becomes embodied in products and is transferred across industries.

The process whereby the R&D investment of one industry becomes embodied in its products which are sold to other industries implies that effectively at any given point in time the products of a certain industry embody its own R&D expenditures and part of the R&D expenditures of the upstream industries from which it is purchasing intermediate and capital inputs. This indirect source of technology -- in addition to own R&D expenditures -- can be estimated using input-output techniques. Thus at the level of the economy as a whole, the total technology embodied in output can be considered to consist of the total economy-wide R&D expenditures and the indirect technology which is embodied in products. Figure 2 shows that this latter “acquired” technology typically accounts for between 40 to 60 per cent of the total technology embodied in output in the 10 OECD countries examined.

These estimated technology levels also allow the calculation of technology multipliers as a measure of the total "technology" embodied in gross output that is obtained from a $1 expenditure in R&D (see Table 1 and Box 1). These are obtained as the ratio of the estimated total technology embodied in output to the R&D directly performed. Most large countries have technology multipliers in the 1.7 to 1.9 region, implying that due to the fact that industries use the technologically sophisticated products of other industries as inputs, the total technology which is embodied in an economy's gross output (to be consumed either as intermediate or final demand) is typically 70 to 90 per cent higher than the value of the R&D expenditures of the manufacturing sector. These multipliers have increased over time in all countries except Denmark, either because industries source more technologically advanced machinery and equipment than in the past, or because the are subcontracting more to other industries.

Box 1. Interpreting the technology multipliers

The technology multipliers are calculated as the ratio of the estimated total (performed and acquired) technology embodied in gross output to the total intramural R&D expenditures (the performed technology) of the manufacturing sector. They indicate the level of total "technology" embodied in gross output that is obtained from a $1 expenditure in R&D.

These technology multipliers are similar to the more traditional output multipliers in input-output analysis, whereby because the output of one industry is an input to other, in order to increase final demand by $1, it is necessary to increase gross output by more than $1.

There is no exact parallel, however, because technology multipliers refer to gross output only. In this context, technology multipliers reflect the public-private nature of technology.

It is well established that knowledge has certain characteristics typical of public goods. It is first partially excludable: it is difficult for firms which undertake R&D to fully appropriate the economic benefits by excluding others from its use. It is also non-rival: new technology can be used many times and in many different processes without being exhausted.

R&D performers and R&D acquiring industries

This broad picture of performed and acquired technology for the economy as whole is composed from the R&D expenditures and the acquisitions of technology of different industrial sectors. At a more disaggregated level, the picture that emerges is that of a cluster of high technology industries performing most of the R&D in the manufacturing sector, and a different cluster of service industries acting as the main purchasers of technologically-sophisticated machinery and equipment.

Table 2 shows the five biggest R&D performing and technology using industries in the 10 OECD countries in the database. The R&D shares for an industry are expressed in terms of its share of total manufacturing R&D. The shares of technology use are expressed relative to the total indirect technology embodied in output, estimated using the methodology explained above. Looking first at the biggest R&D performers, two main characteristics stand out. The first is that one industry, communications equipment in semiconductors, is the first or second R&D performer in 9 out of 10 countries. Chemicals (excluding pharmaceuticals), aerospace, computers and pharmaceuticals also appear on many lists. The second is that R&D performance tends to be quite concentrated in most countries: the top five industries account for 60 to 80 of total R&D expenditures, with the US and the Netherlands exhibiting the most concentration, and Japan and Australia the least.

The list of the industries making the greatest use of equipment-embodied technology in the 10 countries shows that technology diffuses mainly in the services sector. They typically occupy four out of the five top spots in the list of most countries. Social and personal services, an industry category covering among other equipment purchases by the health industry is prominent. The construction industry also appears as an important embodied technology acquirer in 8 out of 10 lists. The transport and storage service industry, real estate and business services, wholesale and retail trade, and government producers also show up as important users of technology.[11]

A few manufacturing industries also make the top-five technology users list in some countries; among them notable are the cases of motor vehicles in Germany and Japan, chemicals in Denmark and the Netherlands, aerospace in the UK and France, and electrical machinery including communications equipment in the Netherlands. A more general characteristic and difference of this list from the list of largest R&D performing industries is its lesser concentration. The top five technology user industries account for less than half (typically 40 to 45 per cent) of total indirect equipment-embodied technology in every one of the 10 countries in the table. Thus the overall picture that emerges is one a few manufacturing industries performing most of R&D, with the products embodying technology being widely diffused in the economy, and particularly in the services sector (Figure 2a).

The presence of services industries in the list of the five largest acquirers of equipment-embodied technology could be explained by their sheer size in the economy. Large industries have more extensive interindustry transactions and should therefore be expected to purchase larger quantities of machinery and equipment incorporating new technology. Table 3 develops an indicator which attempts to correct for size by expressing an industry's share of embodied technology acquisitions in the total relative to its share in economy-wide production.

The table reveals that size by itself does not explain technology use: a number of service industries use in effect technology disproportionately to their weight in production. Communications services is the main industry in that respect, but technology use is intensive also in social and personal services in many countries. The technology content in production does however remain highest in the high technology segment of manufacturing; the indicators varies by country but industries such as computers typically use technology 3 to 7 times more than what their weight in economy-wide production would suggest. These industries are both technology performers and (relative to their weight in the economy) also large acquirers of embodied technology.

Reinterpreting technology intensity

The concept of "technology intensity", usually interpreted as R&D expenditure per unit of output or value added, is widely used as a measure of the technological sophistication of an industry and forms the basis of many comparisons of technological performance. Despite its broad use, the concept is generally not well defined and often does not have a clear correspondence with what it typically aims to measure: ie the adequacy of R&D expenditures or the level of technological sophistication of an industry. One of its main shortcomings is that by focusing exclusively on the R&D expenditures in a particular sector, R&D intensity indicators do not take into account the fact that industries often do little R&D themselves while simultaneously purchasing as inputs highly R&D-intensive intermediate and capital inputs from other sectors domestically and as imports. R&D intensity indicators for such industries will typically have a low value, while the industries themselves may be technologically sophisticated.

The input requirement coefficients derived from input-output matrices provide a tool for the construction of indicators of total technology intensity. These indicators measure the technology intensity in a particular sector by integrating embodied technology measures with measures of the internal R&D carried out by industries to obtain an indicator of combined technology intensity ie by combining direct and indirect (upstream) sources of technology. An approximation of the total technology intensity of a sector can be achieved by assuming that it is a weighted sum of the R&D intensity in all other sectors from which its is purchasing inputs, with the weights being the total input requirements coefficients from these sectors (thus taking into account both direct purchases and second-order effects).

Figure 3 shows the total technology intensities for the 10 OECD countries covered in this study. They are broken down into the part represented by the direct R&D intensity and the part due to indirect R&D inputs, the technology that is acquired through purchases of intermediate and investment goods, domestically and from abroad. The graph suggests that an indicator of the technology intensity of an economy that is based exclusively on the ratio of R&D performed to production is misleading. Acquired technology plays an important role, accounting in some countries for more than the intensity of R&D expenditures.

The contribution of indirect technology inputs to the total technology intensity of economies varies significantly by country. It represents more than half of total technology intensity in Canada and Australia, it has about the same weight as direct R&D intensity in Japan, Italy and the Netherlands, and it is a secondary source of technology in the remaining countries. The important role of acquired technology in Japan implies that while its R&D intensity is about the same as that of the US, accounting for indirect technology inputs through diffusion of technology across industries puts the technological sophistication of the country as measured by the total technology intensity indicator ahead of that of the US. The graph also shows that the increase in the technological sophistication of Japan which took place between 1970 and 1990 came primarily by a more intensive use of technologically advanced equipment and machinery in production, rather than from more intensive R&D expenditures.

This picture at the aggregate level is confirmed by examining the total technology intensity of different groups of industries. Table 4 examines the direct R&D intensity and the total (direct plus indirect/acquired) technology intensity of the high, medium and low technology industry groupings in the manufacturing sector. The high technology group has in effect been defined by its intensity of R&D expenditures in the OECD area, so that by definition its direct R&D intensity is higher than that of medium or low technology industries. The spread however between high and medium technology industry groups varies by country: it is much lower in Germany and in Japan than in the rest of the countries, pointing to a pattern of R&D effort which is more spread out in both high and medium technology manufacturing industries. Japan in particular has the lowest variance of R&D expenditures, with an R&D intensity in its low technology manufacturing industry group that is significantly higher than that of other countries.

Figure 4 looks closer at technology generation and acquisition at the level of individual industries by plotting the total technology intensity profiles for the US, Japan, Germany and France. It shows that when accounting both for R&D expenditures and for acquired technology, despite the large flows of technology from manufacturing to services, it is the industries in the high technology manufacturing group that remain the most technologically intensive. Nevertheless, the incorporation of the diffusion aspect makes the technology profile of countries less skewed towards the traditional high-tech industries, with some services industries in the top ten, as in the case of communications services in Germany and France. Given that in these calculations the service industries were assumed to undertake no R&D of their own, their ranking is almost certainly underestimated.

The importance of capital investment for acquiring technology

Economic theory has accorded great importance to the role of capital in technical change and economic growth, and much new technology is in fact embodied in the capital goods (machinery and structures) that industries purchase to expand and improve production. Capital investment also plays an important role in the diffusion of technology among industries. As final products, machinery and equipment embody research performed by the manufacturing sector, and other sectors obtain access to most of that research through the purchase of capital equipment (computers, autos, airplanes, etc.) that embodies manufacturing research and development.

In order to evaluate satisfactorily the role of capital, however, it is necessary to consider the diffusion of technology through intermediate goods as well. Empirical studies of the relative impact of capital and intermediate inputs on productivity have provided very diverse results.[12] Here, the indicators of acquired embodied R&D developed in this paper are used to analyse this controversial issue by investigating the relative weight of technology embodied in purchased capital (investment) and technology obtained from purchased intermediate inputs.

Figure 5 shows R&D embodied in purchased capital goods as a percentage of all technology acquired by the private enterprise sector in the countries studied. Although these aggregates may be affected to some degree by cyclical fluctuations in capital formation expenditures, the estimated share of technology acquired through capital investment is well below half of the total acquired technology for every country and ranges from 24.5 per cent in the Netherlands in 1981 to 41.2 per cent in the US in 1990. In recent years, the US leads all these countries in the diffusion of technology through capital investment; Denmark has shown the least dependence on capital-embodied technology.

After the downturn of the 1970s, the share of technology embodied in capital investment appears to have increased during the 1980s for most of the countries. For the US and Japan, which have a relatively high level of capital investment, the greatest increase occurred during the 1980s, with a particularly large jump in Japan, which saw a rise of 9 percentage points between 1980 and 1990, and an increase of 5.4 points in the US between 1982 and 1990. Growth was also quite high in the Netherlands, with an increase of 9.1 percentage points over 1981-86. Germany and France have seen a regularly increasing share of capital investment. On the other hand, three countries (the UK, Canada, and Denmark) have failed to recover their level of the early 1970s. Data for Australia is only available for a single point in time, but that country shows relatively high dependence on capital-embodied technology.

Although it is likely that our measurements seriously underestimate the role of capital investment in the diffusion of R&D, the above results tend to confirm that, at the national level, capital investment can be an important means of diffusing the R&D conducted by the manufacturing sector. For every country considered, its share is less than that of intermediate inputs, but that does not mean that capital would not appear as an important factor in the diffusion of embodied technology if our measurements covered R&D embodied in the capital stock which is actually used in the production process, rather than only current flows of new capital goods (investment) as in this exercise.

There can be many reasons for differences in embodied R&D in capital investment at different periods and in different countries. In addition to the impact of business-cycles and interest rate, in the context of this study they include: sectoral R&D expenditures, changes in the composition of industrial sectors, the mix of intermediate inputs in industries (in the Leontief inverse matrix), the relative weight of intermediate inputs and investment expenditures in each sector, the commodity profile of intermediate inputs and investment expenditures, and dependence on procurement of capital goods from abroad. The remainder of this section analyses, at a detailed sectoral level, the underlying factors specific to individual countries and to the different periods.

Table 5 shows, for each of the countries studied, the industries that depend most heavily on capital investment for acquiring R&D. These typically include service sectors, such as communications, finance and insurance, real estate and business services, trade, utilities, and social and personal services.

Petroleum refining, because of its capital-intensive nature, is the only manufacturing sector in the list. The table also shows that, by and large, these service sectors are among the industries that invest the most. In most countries, finance and insurance, real estate and business services, and wholesale and retail trade are the biggest investors and their R&D procurement is quite dependent on investment. For the communications sector, which ranked at or near the top of the list for all ten countries, however, the size of investment is less important than its composition, which is largely information machinery, particularly communications equipment and semiconductors sector.[13]

For most countries, the technology acquired in the services sector through purchases of investment goods showed a rising trend during the 1980s.[14] The fact that the economic weight of these sectors increased rapidly over this period due to deindustrialisation confirms that their share of capital-based R&D diffusion at the national level has risen over the 1980s. By way of contrast, Table 6 lists the five industries least dependent on R&D obtained through purchases of investment goods. The list typically includes those manufacturing sectors which are classified as high-technology sectors (aerospace, computers and office equipment, and communications equipment and semiconductors). They mostly obtained external R&D in the form of intermediate rather than investments goods, and their investment expenditures are also a smaller share of total private investment.

For the services sector, the importance of investment as the principal source of technology acquisition from the manufacturing sector is clear. In addition, although in terms of international trade the services sector is usually classified as "sheltered", it may benefit substantially from foreign technology if its imported capital goods have a large amount of embodied R&D. Figure 6 shows the changing distribution of domestic and foreign sources of acquired technology obtained through capital investment between the first and latest year for which input-output data are available for each country.

First, dependence on foreign technology through capital procurement has increased for every country for which information is available except Japan. Except for Japan and Germany, the increase has been strong, with a share of imported technology that more than doubled in the US and France and increased by five times in the UK. This rapid growth indicates that expansion in the services sector's output and investment has played a major role in increased international trade in high-tech products.[15]

It is possible to define two groups of countries on the basis of their degree of dependence on R&D acquired through imported capital goods. One is composed of the four countries (the US, Japan, Germany and France) for which imports account for less than half of total R&D gains through investment goods purchases. The other consists of those countries for which they are more than half (Italy, UK, Canada, Australia, Netherlands and Denmark). Although there may be many reasons for such differences, the domestic production base of the first group is large, internationally competitive, and covers most of the range of capital goods purchased by the services sector. That is not the case for the second group.

The preceding discussion of the role of capital investment in the diffusion of manufacturing R&D has various policy implications. First, since investment is the only major source of more sophisticated production systems in the services sector, policies could be directed to facilitating access to equipment containing new technology by lowering the investment costs, promoting further technical change in the high-tech manufacturing sector, and encouraging the volume of investment. The information technology cluster (computer, communications equipment, communications services, finance and insurance, and business services), in particular, has played a increasing role in capital-based R&D diffusion; public policy should therefore ensure that the necessary social infrastructures are made available. The ongoing "information highway" programme and other related plans will help strengthen the links between IT clusters by promoting investment in the sectors involved.

A second policy implication concerns the role of international trade. As the services sector in most European countries has procured a large part of its technology from foreign capital goods, international trade is important, both to the manufacturing sector, which sells its products on the world market, and to the services sector, which buys these products in order to modernise its production activities. Accordingly, from the aspect of technology diffusion, protectionist policies directed against a specific manufacturing sector may have adverse consequences for the services sector which is a major purchaser of those products.

Nevertheless, the importance of intermediate inputs as conveyors of technology should not be underestimated. This source of technology is particularly important for constructing effective production systems in high technology manufacturing industries, and it has helped establish an efficient services sector. If a country lost this source of technology, it would have to depend excessively on imported machinery, and that would have a negative impact on growth and technical change.

International technology transfer: the role of imports in the diffusion of technology

In the past few years, the pace of technology transfers has been increasing rapidly, particularly among the OECD countries, making the issue of international technology diffusion particularly important (Nadiri, 1992). Statistics on the technology balance of payments (TBP) among OECD countries relate to trade in licences and know-how and are one measure of (disembodied) technology diffusion across borders. They indicate a rapid increase in technology trade, with a substantial increase in the total volume of transactions in international technology markets (obtained by summing the receipts from technology sales and import payments for technology purchases).

Another measure of interest is the international diffusion rate, calculated as the ratio of the number of external patent applications to the previous year's domestic patent applications. This is a simplistic measure of technological diffusion among countries and suffers from all the shortcomings of patent measures noted earlier. It can serve, nonetheless, as a general indicator of international technology diffusion It shows that, since 1981, the diffusion rate has increased for most OECD countries, and that research-intensive industries, such as electronics, communications, aerospace, and pharmaceuticals, where international expansion is rapid, command the major share of technology trade. Rather than through licensing, technology transfer usually occurs through joint ventures, sales of technology, supply of turn-key plants, etc.

Multinational firms play an important role in international technology diffusion. R&D activities and transfers of technology often follow on foreign direct investment (FDI). In countries with large stocks of FDI, a relatively large share of business R&D is performed by foreign affiliate firms. A recent and important form of technology transfer involves international co-operative agreements, often between US, European, and Japanese firms, to undertake joint technology development ventures. It concerns research-intensive and often science-based industries such as biotechnology, communications, electronics, etc., and is dominated by multinational firms.

The methodology developed above can also be used to examine more closely the international aspect of equipment-embodied technology diffusion. Just as technology can be diffused between industries *within* a country, increasingly it can also be diffused *between* countries embodied in imports of intermediate goods and capital equipment. Figure 7 shows that the share of acquired technology obtained from imports has increased over time for all the countries studied, except Japan. The level of acquired technology obtained from imports is inversely related to the size of the country's economy;[16] this reflects the fact that bigger countries do more R&D, tend to be more self-reliant, and benefit from more extensive linkages among domestic firms, which raise the level of domestically acquired technology. Smaller countries typically depend on imports for over half of their acquired technology. Yet even for the US, the amount of technology acquired through imports has more than tripled over the last two decades.

The growing importance of imports is in keeping with the overall increase in international trade, which has outpaced growth of GDP throughout the OECD area. More specifically, the rising technological content of trade tends to be associated with three interrelated factors: the continued specialisation of technologically sophisticated production (Archiburgi and Pianta (1992), OECD (1994a); the need for businesses to recover R&D costs by expanding the market for their products through exports; and the increasing tendency for firms to engage in intrafirm trade with foreign affiliates, even though R&D is still typically performed in the home country (OTA, 1994; OECD 1994f). Although the specific role of these factors is not clear, they help explain why imports are more important for some sectors than for others and why patterns of technology flows between trading partners differ.

Identifying the sources of change

The connection between a country's size and its propensity to acquire technology through imports breaks down when the focus shifts to the rate of change. The UK and the US registered the fastest growth in technology acquired through imports (with annual average growth rates of 7.8 and 6.8 per cent, respectively), while Denmark and Canada had low growth rates (only 0.5 and 1.0 per cent) and Japan registered negative growth (-0.7 per cent). In the countries registering a growth in technology acquired through imports, the growth tends to be sector-specific, with two or three sectors typically responsible for the bulk of the gain (Table 7). The most important sectors vary from country to country: chemical imports are the chief source of imported technology in Denmark and the Netherlands, motor vehicles in Germany, and aerospace in the UK. However, for countries with an increase in imports, two sectors frequently appear among the top three: computers and office machinery in more than half and communication and semiconductor equipment in three out of seven.

Three phenomena help explain why these sectors are important to the increasing role of imports as a mechanism for technology diffusion: 1) they are relatively new technologies; 2) their production structure is more globalised; 3) they originated in relatively few countries, so that international trade was a necessary diffusion mechanism. Each of these assertions are supported by the analysis:

- The importance of the two information technology (IT) sectors, computers and communication and semiconductor equipment, as a source of acquired technology embodied in imports is typically most pronounced in the latest period for which data is available. In Canada, over 80 per cent of the total increase for these sectors occurred from 1986 to 1990, in France, more than 50 per cent from 1982 to 1985, in the UK more than 50 per cent from 1979 to 1984, and in the US under half from 1985 to 1990.

- Recent case studies of these sectors indicate that in order to gain market access and enter into alliances so as to share the rising costs of R&D in this field, IT firms have "globalised" to a much larger degree than other sectors. This has meant a much higher level of exports and imports per unit of production. Two-thirds of this trade was intrafirm trade of semi-finished parts between corporate affiliates located in different countries (the average in manufacturing is one-third)

- Aside from its imports from the dynamic Asian economies (DAEs), the US is the leading source of this technology for the other countries. The second largest supplier never reached 60 per cent of the US share. Given the concentration of this technology, trade is the primary mechanism for its diffusion.

Domestic vs. imported acquired technology

The importance of imports as a means of acquiring technology becomes apparent when their effect on technological intensity (total acquired technology divided by production) is compared to that of domestic sources. For all industries, as Table 8 shows, imports were more important than domestic sources in Canada, Denmark, and the Netherlands, while in Australia and Italy, the two sources were about equal. Only in the US, Germany, and Japan were domestic sources more than twice as important as imports. If only the five sectors which registered the largest gain in intensity from acquired technology are examined, imports are the most important source of acquired technological intensity for over half of these sectors. Again, the influence of imports on the technological intensity of a sector is inversely related to the size of the economy. In small countries such as Australia, Denmark, and the Netherlands, imports are the major source of acquired technology in over 90 per cent of the top five sectors, while for the US, Germany, and Japan they are key in only 20 per cent. However, for aerospace and for computers and office equipment, which appear in the top five for nearly all the countries, the importance of imports exceeds or equals domestic sources of acquired technology in almost every case.[17]

When analysed over time, changes in the technological intensity of all industries were overwhelmingly due to imports in five of the eight countries and were due about equally to domestic sources and imports in two (Germany and the US). Only in Japan were domestic sources of acquired technology significantly more important than imports. By and large, the impact of imports was most pronounced in the period extending from the mid-1980s to the late-1980s or 1990. Of the sectors where technological intensity fell over time, two-thirds of the drop was due to a decline in technology acquired from domestic sources, most often during the period from the early 1970s to the mid- or late-1970s.

Technology acquired from other countries

Responsible for almost half of the R&D performed by manufacturing industries in the OECD area, the US is also the most important source of technology acquired through imports (OECD, 1994). From a high of 75 per cent of all technology acquired through imports by Canada to a low of 28 per cent by the UK, the US was the most important source of acquired technology for five of the other nine countries (Table 8). The share of technology acquired through imports from any one country varies widely. Canada and Japan are the most dependent upon a single country and Italy is the least.

For the five industries that gained the most technological intensity from acquired technology, the US was the most important supplier for 60 per cent of the sectors; for the aerospace and computers sectors, which figured among the top five in almost all countries, the US was the main source for eight of the nine other countries for aerospace technology and for all eight for computer technology. For the US, the DAEs are the main source of technology acquired through imports for the five industries which benefit the most from acquired technology, but Japan is the largest overall source of acquired technology. This suggests that while Japan is not the principal source for the top five industries, it supplies large quantities of technology of a type which is commonly considered medium or low technology, such as motor vehicles, ferrous metals, and stone, clay, and glass.

While the US is a large performer of R&D and a centre for particular types of technology, its predominance as a supplier of technology embodied in imports might simply reflect the fact that it is the largest economy in the OECD area and has the second largest export market share among the countries studied (OECD, 1994). Is its role as a supplier of technology disproportionately large?

In order to answer this question, Table 9 provides a list of the three largest suppliers of technology for each country and the share of this trade valued in US dollars. The US was the primary source of technology acquired through imports and among the top three suppliers to each of the countries in the sample. Germany was in the top three for six countries. Surprisingly, Japan was among the top three for only three countries, all of which border on the Pacific: Australia, Canada, and the US. By and large, these flows reflect general trading relationships between countries. Australian technology imports from Japan roughly match Australia's overall share of imports from Japan; based on the currency value of trade, the share of technology imports divided by the share of imports gives a ratio of one (col. 5 of Table 9). This indicates that trade between these two countries is technologically neutral: it is not skewed towards products with a high technological content (technology-positive), nor is it composed mainly of items embodying little technology (technology-negative).

The US is the exception to this rule. Exports from the US to the other nine countries consistently are technology-positive, with the share of technology usually twice the share of value. The only other cases of technology-positive trade are German imports from France and all three of the major trading partners if the US: Japan, the DAEs, and the Rest of the World (RoW). Paradoxically, the US not only provides a disproportionate share of technology in its trade with other countries, but it also receives a disproportionate share.

While in the aggregate the US is the principal source of imported technology, each country has a comparative advantage or specialisation in some area. To identify these pockets of specialisation, for each country, the share of technology acquired through imports from a particular sector was divided by the share of technology acquired through imports from that country for all products. If the ratio is above one, the country of origin is considered to have a specialisation in that technology. For example, in 1985, France received from Germany 19.2 per cent of the total technology it acquired through imports and 32.4 per cent of its technology embodied in motor vehicle imports; this results in a technology specialisation index of 1.7 -- Germany enjoys a technological specialisation in motor vehicle technology with France. Because the ratios are not additive, summary measures cannot be drawn, but in terms of frequency, the countries have the technological specialisation shown in Table 10. By and large, a country's technological specialisation with one of its trading partners is one it enjoys with all of its trading partners. The main exceptions involve the regional groupings of countries (the rest of the OECD, the DAEs, and the RoW), where the mix of countries results in different patterns of technological specialisation with different trading partners. The DAEs specialise in textiles when they trade with Australia, Canada, and Japan but in communications and semiconductor equipment in trade with Germany, Italy, the UK, and the US.

Technology clusters: identification of the types of technology acquired

While it is important to know whether technology is acquired from intermediate goods or capital goods or from imports or domestic sources, the most fundamental distinction concerns the type of technology being diffused. Identifying which technologies are being acquired and which are not and how trends change over time and differ among countries can give insight into the diffusion process which has implications for diffusion policies. As previous sections have shown, industries do not all have the same propensity to acquire technology: some are self-sufficient, some rely on technology developed by others. What is the relation between these differences and the types of technology being acquired? In other words, do some types of technology have characteristics which require that firms develop the technology themselves while others are easily transferred? The identification of the technologies most prone to diffusion and most likely to be acquired by user industries can be used to refine policies designed to foster technology diffusion to improve productivity and competitiveness.

This section focuses on these issues by describing the relative importance of different types of technology and by examining which sectors acquire which technologies and how trends differ over time and across countries. For reasons of presentation and comparability of countries with different industry aggregations, five "clusters" of similar technologies have been defined: information, transportation, consumer goods, materials, and fabrication. (Box 2 shows the various sectors included in each of these clusters.) Because, as used in this analysis, technology is the R&D embodied in intermediate inputs and capital equipment produced by the manufacturing sectors, the source for all acquired technology is, by definition, the manufacturing sector. However, technology is also acquired by other sectors, including agriculture, mining, manufacturing, and services. Again, for ease of presentation and to improve comparability across sectors, the acquiring sectors have been aggregated into 13 broad groups: 1) agriculture; 2) mining; 3) low-technology manufacturing; 4) medium-technology manufacturing; 5) high-technology manufacturing; 6) electricity, gas and water (EGW); 7) construction; 8) wholesale and retail trade and hotels and restaurants; 9) transportation services; 10) communication services; 12) finance, insurance, and real estate (FIRE); and 13) social and personal services.

Box 2. Cluster Classifications

Cluster	**Industry**
INFORMATION	Computers, Communication & Semiconductor Equipment, Electrical Machinery, Instruments
TRANSPORTATION	Shipbuilding, Aircraft, Motor Vehicles, Other Transportation
CONSUMER GOODS	Food, Bev. & Tobacco, Textiles, Apparel & Footwear
MATERIALS	Agriculture, Construction, Mining, Paper & printing, Wood products, Stone, clay & glass, Ferrous metals, Non-errous metals, Chemicals, Pharmaceuticals, Petrol. Refining, Rubber & Plastics
FABRICATION	Fabricated Metal Products, Other non-electrical machinery, Other manufacturing

The types of technology being diffused

Figure 8 shows that for six of the ten countries, information technology (IT) made up the bulk of the technology being acquired, with over 40 per cent of all acquired technology for these countries in the most recent period. For the US, the Netherlands, and Canada, IT has historically been the most important technology acquired, while this has only recently been the case for France and the UK. The importance of IT has increased for seven of the eight countries for which there is more than one data point. It is by far the fastest-growing acquired technology, averaging over a percentage point gain in share per year for the countries for which historical data is available.

With one or two exceptions, the shares of the other clusters either held steady or declined over the period. Nevertheless, they are important shares of total diffused technology. Material technologies -- chemicals, basic metals, and rubber and plastics -- were the most important acquired technologies for Japan and Denmark. This cluster was also important in Germany and Italy, where it shared first place with IT. It was the second most important cluster for six of the remaining countries, averaging about a quarter of total acquired technology. However, it is the technology whose share has fallen the most, averaging over a percentage point loss in share annually. The third most important technology cluster was the transportation group (aerospace, motor vehicles, and shipbuilding), which typically provided about a fifth of total acquired technology; it has remained quite stable over time. The fabrication technology cluster, consisting of fabricated goods such as stamped sheet metal and non-electrical machinery such as machine tools, represented about a tenth of all acquired technology. The consumer goods technology cluster, which includes technologies associated with textiles and apparel and food processing, played a small role, contributing only 1 or 2 per cent of the total.

Tracing the change in technology clusters to acquiring sectors

As Figure 8 shows, information technology makes up over 40 per cent of acquired technology in most countries and is the only technology with a consistently increasing share over time. Where does this technology go? Which sectors are increasing their use of IT? Conversely, what is the source of the decreasing share of materials technology?

To track which sectors were associated with the gain or loss in share of a particular technology cluster, the distribution of technology acquisition was calculated across sectors for each time period, and then the gain or loss over time was calculated. For example, in Canada in 1971, about 16 per cent of acquired IT went to the high-technology sector. By 1990, the share had risen to 27 per cent, a gain of 11 share points. But as one sector gains, others lose. In this case, low-technology manufacturing, EGW, and construction lost shares to balance the gain in high technology. In all countries, high-technology manufacturing, communication services, FIRE, and social and personal services have increased the share of acquired technology they obtain from the IT cluster. Canada, France, the UK, and the US all registered more than a 7 point increase in the use of IT by high-technology manufacturing.

All told, for every country for which a change over time could be calculated, there was an increase in the share of IT going to the high-technology sector, although only of 1 point in Japan. This phenomenon may have several causes, including the fact that "knowledge intensity" has increased in manufacturing, with the result that more and more IT inputs are needed; one example is the latest generation of aircraft, which makes increasing use of IT inputs for navigation, communication, and entertainment. Another is the increasing specialisation of IT hardware producers. In the early 1970s, many computer firms were vertically integrated, producing their own microchips, disk drives, and monitors for their mainframes. By 1990, the advent of specialised suppliers for particular components meant that a huge proportion of all integrated microconductors and flatscreens were sourced from one or two suppliers. The increased use of specialised suppliers for technologically sophisticated IT components shows up as an increase in the diffusion of information technology.

The pattern of an increasing share of IT was less uniform for the services sector: Japan, the UK, and the US saw share gains of at least 4 points in the FIRE sector; Canada and the US had share gains of 3 points in the social and personal services sector; and Denmark and Germany had gains of 2 points or better in communication services. Although the increase is small when compared to the increase in high-technology manufacturing, it is indicative of the changing nature of services, which use IT to automate office work, create new products, and link previously distinct activities.

In materials technology, acquired technology lost shares in two sectors: low-technology manufacturing and construction. The decline is probably related to the general decline in the intensity of use of materials, which is affecting most countries as the distribution of output shifts to other sectors and substitutes are found (Williams et al., 1987). For example, in the US between 1972 and 1990, the share of chemical technology acquired by the textile industry fell by 4.9 share points; this is in keeping with the fact that the share of GDP contributed by the textile industry fell.

Links between individual technology clusters and the acquiring sectors

As of the mid-1980s or 1990, there is a clear pattern of flows of technology from different clusters to various acquiring sectors. To show the differences in these flows, an index of disproportionality of use was created by dividing the share of a particular technology acquired by each sector by the average for all sectors. Thus, if the high-technology sector obtained 75 per cent of all its acquired technology from IT and the average across all sectors was 47 per cent, the index would be 1.6 (75/47). Sectors with an index above 1.0 would be disproportionately high acquirers of that technology cluster, while those under 1.0 would be disproportionately low acquirers. Using this filter, Table 10 aggregates each sector's principal acquired cluster technology with their corresponding index of use. The table shows that certain types of technology tend to gravitate towards certain sectors:

- IT towards high-technology manufacturing, communication services, and FIRE;
- transportation towards transportation services;
- consumer goods towards wholesale and retail trade;
- materials towards agriculture, low- and medium-technology manufacturing;
- fabrication towards mining, EGW, and construction.

In addition, the table shows two other trends. First, these links exist, by and large, in all countries. For the IT cluster, all of the countries had an index above 1.0 for the three sectors, and the same was true for most of the clusters. Only in a few instances, such as the acquisition of consumer goods technology by wholesale and retail trade in Australia and Denmark, did the index fall below 1.0. Thus, the linkage between the type of technology being diffused and the sector acquiring the technology holds regardless of country.

The second trend is reflected in the average index. Some technologies, such as IT and materials, are more evenly distributed than others, such as transportation and consumer goods, and therefore have a lower average disproportionality index. This reflects the fact that these technologies are more commonly used over a wider cross-section of industries. Transportation technologies, such as aerospace, are less general and are typically used only by the transportation services sector (airlines) and therefore have a much higher disproportionality index.

The role of imports

As seen above, the importance of imports as a means of diffusing technology varies across the various clusters. For each country and cluster, Table 11 compares the share of total acquired technology to the share of imported acquired technology. If the technology is trade-neutral, the cluster's share of imports should match its share of the total, resulting in a ratio of import share to total share of 1.0. If a disproportionate amount of acquired technology comes from imports, the ratio would exceed 1.0. Table 12 shows that, for most countries, information and transportation technology clusters tended to be imported. This was especially true for transportation technologies, as all ten countries obtained a disproportionate amount of this technology from imports. For information technology, the role of imports was more mixed, with five of the ten countries exhibiting an index above 1.0, and only one country

(Canada) with a ratio significantly below 1.0. On the other hand, the materials and consumer goods technology clusters were disproportionately domestic, with only one or two countries obtaining a greater share of acquired technology from imports. Finally, the fabrication technology cluster was very mixed, with about half of the countries favouring imports as a source of this technology.

These results have several implications for diffusion policies, the first of which is the need for such policies to target all sectors, especially services. Typically, government programmes for diffusing technology concentrate on transferring technology to the manufacturing sector. These results suggest that services -- such as finance, insurance, and real estate, wholesale and retail trade, and communication services -- are also important acquirers of technology. The second broad implication is that the not all technologies should be given the same priority when it comes to diffusion; some have wider application than others. This would suggest that, given limited resources, the first priority of diffusion programmes should be to diffuse information and materials technologies which answer the needs of many sectors

IV. Conclusions

This paper examined the intersectoral and international patterns of technology diffusion in 10 OECD countries. It developed a methodology which allows the calculation of measures of technology diffusion based on the purchases by industries of intermediate and capital inputs (domestically and from abroad). On the basis of these calculations, the paper examined a number of issues: the patterns of supply and demand of technology; the adequacy of existing indicators of technological level of industries for guiding policy; the role of capital equipment purchases in technology diffusion; the importance of imported technology; and the role of technology clusters, especially that of information technologies.

In terms of the supply and demand of innovations, the analysis revealed that while innovations are developed mainly in a cluster of high technology manufacturing industries, the main acquirers of technologically sophisticated machinery and equipment are a different cluster of industries in the services sector. The use of technology in many service industries (especially private services) is higher than what their (large) weight in the economy might suggest. The part of total technology embodied in output which is acquired externally has increased over time, either because of more extensive sourcing of high technology goods or because of changes in the strategies of firms (more subcontracting).

This suggests that simple R&D intensity indicators are a misleading measure of technological sophistication of industries; "total technology" indicators at sectoral level combining both performed R&D and externally acquired technology are more appropriate. The distinction between high, medium and low technology industries blurs when accounting for the purchase of technologically sophisticated inputs. The technology intensity of small countries increases significantly with acquired technology; big increases can also be seen in the technology intensity of medium technology industries in Japan, Germany, Canada, Netherlands; the overall total technology intensity for Japan overtakes that of the US.

In terms of the role of capital inputs in technology diffusion, the estimated share of technology obtained through capital investment is less than 50 per cent of total acquired technology for every country (but this is probably an underestimate); the US leads in the diffusion of technology through capital investment. The industries most depended on investment-based technology acquisition are in services (finance and insurance, social and personal, communication services); those least dependent are the high technology manufacturing industries.

Bigger countries source less technology from abroad than smaller countries which depend on imports for more than 50 per cent of their acquired technology; the share of acquired technology through imports has increased over time for all countries except Japan. In intensity terms, imported technology is more important than domestic technology for all countries except the US, Germany and Japan. The US is the most important source of technology for all countries (especially for computers and aerospace); for the US, the DAEs and Japan are the most important source of technology acquired through imports.

Technology emanating from the information technology cluster of industries is the bulk of technology acquired in most countries; the materials technology cluster (chemicals, basic metals, rubber, plastics) is important in Japan, Germany, Italy, Denmark. The importance of information technology has increased over time; IT is the fastest growing acquired technology cluster; the share of other technology clusters is steady or declining. Certain types of technology tend to gravitate to certain sectors: information technology to high technology manufacturing, communications services and finance, insurance and real estate; transportation technology to transportation services; consumers goods technology to wholesale and retail trade; materials technology to agriculture, and to medium and low technology manufacturing; and fabrication technology to mining, utilities and construction.

The mapping of intersectoral and international technology diffusion flows and the calculation of various measures of technology diffusion is the first step in the analysis of the impact of technology on productivity, employment and international competitiveness using industry-level data. The next step in the analysis is to introduce these measures of diffusion alongside measures of the intensity of R&D performance as determinants of medium-term productivity growth, employment and export performance in OECD countries. This next phase will thus allow an empirical examination of the productivity growth and employment performance of different types of industries according to how they develop and use technology developed elsewhere, either domestically or from abroad.

TECHNICAL APPENDIX

This appendix provides a detailed technical description of the model in the paper. It attempts to present a clear and complete statement of the methodology used, and to provide a thorough discussion of the many technical issues. It gives an algebraic presentation for the R&D embodiment indicators described in the main text and describes various OECD databases used.

Embodied R&D indicators

The methodology on technology diffusion and productivity growth used in this project builds on the seminal work of Terleckyj (1974) and other researchers (notably, Scherer (1982), Davis (1988), Goto and Suzuki (1989), Griliches and Lichtenberg (1983)) which used input-output based technology flow matrices to measure the impacts of inter-sectoral technology flows on economic growth.

As stated in the main text, the technology indicators focuses on R&D embodied in products purchased by an industry (intermediate inputs and investment goods). This "R&D embodiment" concept relies on the fact that market commodity flows among industries can be regarded as the means for the transfer of technology developed by supplying industries. The use of input-output tables can help capture interindustrial flows of technology which are not otherwise observable.

In contrast to previous OECD work (Sakurai, Wyckoff & Papaconstantinou (1993)) which directly uses input-output tables to capture embodied R&D in purchased products, the current R&D embodiment indicators have been formulated on the basis of a Leontief inverse, taking into account the cumulative nature of interindustrial R&D flows. The merit of the Leontief inverse model enables the measurement of second-round R&D gains for a specific industry of R&D performed by industries elsewhere.

Such multiplier effects in R&D embodiment estimates can be important. The semiconductor industry for example undertakes a large amount of R&D in many OECD countries. New models of automobiles or airplanes are increasingly equipped with high-quality electronic components for automatic engine control or advanced navigation systems. However, these downstream users of electronic products frequently do not directly purchase them from semiconductor industry; instead those products are already embodied in parts which were manufactured by engine and instrument producers. The use of direct input-output coefficients fails to take into account of such technological advance embodied in electronic parts in the calculation of the R&D content of autos or airplanes and only the Leontief inverse model can provide the precise measurement of total R&D embodiment in products by its nature of multisectoral multipliers.

In an input-output framework, two kinds of technological gains can be traced: industrial R&D embodiment and the R&D content of final demand (domestic final demand and exports). The latter aspect was first introduced by Davis (1988). For measuring industrial R&D gains, the input-output database used in this project provides four major components of indirect R&D indicators for each industry: (i) R&D gains embodied in purchased domestically produced intermediate inputs; (ii) R&D embodied in imported intermediate inputs; (iii) R&D embodied in purchased domestically produced capital goods; and (iv) R&D embodied in imported capital goods.

The imported portions of technology can be further broken down into countries of import origin: for example, in the US, sourcing countries of the imports are separated into 12 regions: other six G7 countries, Australia, Denmark, the Netherlands, other OECD, DAEs+China and the rest of the world (see below for the description of the trade database). The total R&D gains for a industry is a total sum of these four components.

Total R&D embodied in domestic final demand and exports

1. For a country, the balance equations of gross output in an open static input-output system can be written as:

$$X = A^d X + F^d + E \qquad \text{(A-1)}$$

where X is the vector of gross outputs, A^d is the matrix of domestic input-output coefficients, F^d final demand vector for domestic outputs and E is the exports vector (for simplicity, suffixes of country and years are omitted). Solving the domestic balance equation for X, we obtain the equilibrium production to satisfy given final demand:

$$X = (I - A^d)^{-1} [F^d + E] \qquad \text{(A-2)}$$

As an approximate measure of technological sophistication, we define the direct R&D intensity as R&D expenditures per gross output for industry I:

$$r_i = \frac{R_i}{X_i} \qquad (i = 1,2,\ldots n) \qquad \text{(A-3)}$$

2. Although it is widely recognised that R&D investment has a certain lag before its commercialisation (average lag is 2-3 years in the existing literature) and as an indicator of product sophistication R&D stock variables are more appropriate than flow ones, current R&D expenditures were employed in estimating flows of technology for a particular year. Since these omissions may significantly affects the resulting indicators, sensitivity tests are to be conducted.

Combining equation (A-2) with (A-3), the vector of domestic total R&D embodiment, T^d, can be then defined by pre-multiplying the diagonalised matrix of sectoral R&D coefficients (A-3) to equation (A-2), so that we obtain:

$$T^d = \hat{r}(I - A^d)^{-1} [F^d + E] \qquad \text{(A-4)}$$

where hat (^) denotes a diagonal matrix whose elements consist of the corresponding vector.

Equation (A-4) connects domestic R&D embodiment with final demand components (domestic final demand and exports). The *total domestic R&D embodiment per unit of final demand for industry j* can be then defined as the jth column sum of the above coefficients matrix:

$$rf_j = \sum_{i=1}^{n} r_i b_{ij} \qquad (j = 1,2,\ldots,n) \qquad \text{(A-5)}$$

where b_{ij} are the elements of inverse $B = (I-A^d)^{-1}$. Since the jth column sum of the Leontief inverse B measures the total (direct and indirect) impacts on domestic production when final demand for the jth sector changes by unity, equation (A-5) provides the total amount of R&D per unit of the final delivery of output j.

In an open economy, imports are also an important source of technological advance. Final consumers can gain not only from domestic R&D activities but also from R&D conducted by foreign suppliers. In addition, since the production for exports indirectly induces demand for imported inputs, export-induced foreign R&D should be equally taken into account. To formulate these imported elements, the balance equation for imports in an input-output system is written as:

$$M = A^m X + F^m = A^m B F^d + F^m + A^m BE \tag{A-6}$$

where A^m is the input-output coefficients for imported inputs and F^m portion of domestic final demand for imports. The first two terms of the last equation are imports induced by domestic final demand and the last term defines those induced by exports.

Applying imports shares by country of origin for each products, imported parts of R&D in domestic final demand and exports could be estimated by the following equation:

$$T^m = \sum_{k=1}^{l} \hat{r}_k \hat{\alpha}_k [A^m B F^m + F^m] + \sum_{k=1}^{l} \hat{r}_k \hat{\alpha}_k A^m BE \tag{A-7}$$

where r_k are sectoral R&D intensities for country k (k=1,..,l) and α_k are sectoral shares of imports by country of origin. Note that since direct R&D intensities are used to define imported R&D, the imported part of R&D cannot avoid significant underestimation of import contribution in our model. To keep consistency with domestic R&D embodiment, the use of total R&D intensities are more preferable, but it causes several difficulties in actual calculation due to simultaneous characteristic among the variables. Taking into account such imported elements of R&D, total R&D embodied in domestic final demand and exports is simply a sum of domestic total R&D embodiment T^d and R&D embodied in imports T^m.

Using equation (A-6) and (A-7) and exports shares by country of destination, R&D exports from a country to country or region k can be defined as:

$$T^e{}_k = \hat{\beta}_k (\hat{r} BE + \sum_{k=1}^{l} \hat{r}_k \hat{\alpha}_k A^m BE) \tag{A-8}$$

where β_{ik} is the export share of export product i to country k. Although our model is not able to properly define the *technology balance in trade*, the precise formula is not likely to be given due to asymmetric definition between domestic R&D and imported R&D embodiment as we have noted above.

Total R&D embodiment of industry

The calculation of total R&D embodiments in purchased intermediate goods for industry j is slightly different from the above equation (A-5). The traditional Leontief multipliers B tells us how much R&D is directly and indirectly embodied in one unit of final demand for output j, but not how much R&D is embodied in industry output j. From an industrial aspect, the measure of industry's R&D embodiment thus should be defined from an output basis in order to address the latter question. As shown for example by Miller and Blair (1985) p.328, the modification of the standard Leontief model can be easily done by using the following output-to-output based multipliers:

$$\begin{bmatrix} 1 - a^d{}_{11} & -a^d{}_{12} & \cdots & -a^d{}_{1,n-1} \\ -a^d{}_{21} & 1 - a^d{}_{22} & \cdots & -a^d{}_{2,n-1} \\ \vdots & \vdots & \vdots & \vdots \\ -a^d{}_{n-1,1} & -a^d{}_{n-1,2} & \cdots & 1 - a^d{}_{n-1,n-1} \end{bmatrix}^{-1} \begin{bmatrix} a^d_{1,n} \\ a^d_{2,n} \\ \vdots \\ a^d_{n-1,n-1} \end{bmatrix} = \begin{bmatrix} \frac{b_{1,n}}{b_{n,n}} \\ \frac{b_{2,n}}{b_{n,n}} \\ \vdots \\ \frac{b_{n-1,n}}{b_{n,n}} \end{bmatrix} = B^*{}_n \tag{A-9}$$

The above adjusted multiplier vector indicates the direct and indirect output requirements from all the sectors excluding industry *j* to produce one unit of *output* for industry *n* (suppose for convenience that industry $j = n$). We thus define the adjusted multiplier matrix as $B^* = [B_1, B_2, .., B_n]$.

This *output* multipliers are less than or equal to traditional Leontief multipliers defined by *final demand* since the propagation process of interindustrial demand can be reduced by the exclusion of industry *j* in propagation, keeping the industry's output constant during this process and hence R&D amounts conducted by this industry. While the use of the traditional Leontief multipliers cannot avoid the double-accounting of the R&D embodiment of industry *j* by the extend of increase in industry *j*'s output during the propagation, the use of such adjusted multipliers enables us to exactly define total R&D embodiments of industry *j* by the simple sum of direct R&D actually conducted by this industry and indirect R&D embodied in the purchased products (total R&D = direct R&D + indirect R&D). This model is useful to define direct and indirect R&D intensities without including double-counting of these R&D elements.

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

$$TINT^d_j = \sum_{i \neq j}^{n-1} r_i \, b^*_{ij} \, X_j \qquad \text{(A-10)}$$

The R&D embodied in purchased domestic capital goods for industry j can be defined as:

$$TINV^d_j = \sum_{i=1}^{n} r_i \Big(\sum_{k=1}^{n} b_{ik} \, I^d_{kj} \Big) \qquad \text{(A-11)}$$

where I^d_{kj} is industry j's investment expenditures for *i*th product. Since investment expenditures are one of the components of final demand, the traditional Leontief inverse can be applied to define the indirect R&D embodied in purchased capital goods.

The embodied R&D counts only the R&D embodied in current capital formation and neglects the R&D embodied in the stock of capital operated for production. Because of past capital formation and its technology quality, hence, the indicators of capital-embodied R&D calculated can underestimate the actual R&D contribution of capital. Since the revision of this part of the model requires additional data (time-series data on investment flows matrix, investment deflators, etc), the static formulation is retained for the moment.

Compared with the treatment of domestic R&D flows, the formulation of imported R&D is quite simple in the sense that current model does not consider the interindustrial propagation effects in acquired R&D counting. First, *R&D embodied in purchased imported intermediate inputs for industry j* is defined simply by multiplying foreign direct R&D intensities with the imported amount of intermediate demand as:

$$TINT^m_j = \sum_{k=1}^{n} \sum_{i=1}^{l} r_{ik} \alpha_{ik} \, X^m_{ij} \qquad \text{(A-12)}$$

where X^m_{ij} is the intermediate demand for product *i* by industry *j* and α_{ik} the import share of country *k* for import *i*.

Similarly, R&D embodied in purchased imported capital goods for industry j can be defined as:

$$TINV^{m}{}_{j} \;=\; \sum_{i=1}^{n}\sum_{k=1}^{l} r_{ik}\,\alpha_{ik}\,I^{m}{}_{ij} \qquad \text{(A-13)}$$

where I^{m}_{ij} is the investment demand for product *i* by industry *j* and α_{ik} the import share of country *k* for import *i*.

In the absence of indirect effects, the above two equations may cause a serious underestimation of imported R&D elements. An improvement of the model is difficult for a number of reasons. One difficulty relates to whether such indirect effects should be taken into account by using the inverse of the producing country or that of the importing country; in the former case the model should be solved simultaneously across countries as every country is linked to another by international trade. Another question is whether the indirect ripple of imported R&D should be counted as if it were done for domestic products. In counting indirect R&D, the distinction of imported and domestic products may not be appropriate because down-steam industries (auto) can acquire the R&D gains from imported high-tech machines installed in up-stream industries (iron). Due to such difficulties, we use the above simplest type of equations to evaluate the amount of imported R&D component for both intermediate and capital goods.

Lastly, *total R&D embodiment for industry j* can be defined as the simple sum of these four R&D components:

$$TTTL_{j} \;=\; R_{j} \;+\; TINT^{d}{}_{j} \;+\; TINV^{d}{}_{j} \;+\; TINT^{m}{}_{j} \;+\; TINV^{m}{}_{j} \qquad \text{(A-14)}$$

The first term of equation (A-14) shows the amount of direct R&D and the other four terms denotes denote 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, ie, R&D embodiment per unit of output, can be simply calculated by dividing each term of the above equation by the amount of output X_j.

It is noted that the use of the adjusted Leontief multipliers shown in equation (A-9) allows the separation between direct R&D R_j and its domestic indirect effects $TINT_j^d$, avoiding the double counting of R&D embodiment. In addition, the above formula is also consistent with its intensity version, because $TINT_j^d$ is defined on the basis of the *output* of industry *j*, not the final demand for industry *j*.

As shown in the next section, these R&D indicators can be applied to capture the impact of inter-industrial flows of technology on productivity growth. Innovations fundamentally affect productivity in industries performing R&D, but the returns also flow into downstream industries that use their products in the production process. Since the above indicators are defined not only for manufacturing sectors which are major R&D-conducting sectors but also for non-manufacturing sectors which typically depend on sectors within manufacturing for much of new technology, it is possible to measure the indirect productivity effects in downstream industries which are able to acquire better quality capital or materials produced by research-intensive industries.[18]

The OECD databases used

A number of OECD databases were employed in the project: from the STAN database family developed in the Directorate for Science, Technology and Industry: R&D expenditures (ANBERD), input-output tables, and bilateral trade.

The STAN database family attains a relatively finer level of manufacturing disaggregation (22 industries), using a common industrial classification (ISIC Revision 2) which allows the identification of technology- and trade-intensive industries such as pharmaceutical, aerospace, computers, and communication equipment & semiconductors. This industrial detail helps identify clusters of industries that share R&D through embodiment and analyse the role of international trade in the acquisition of technology developed abroad. The databases explained below commonly cover all the 10 OECD countries analysed in the project -- Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, the UK and the US.

Analytical Database of Business Enterprise R&D (ANBERD)

The ANBERD database was constructed with the objective of creating a consistent data set of R&D performed by the business sector that overcomes the problems of international comparability and time discontinuity associated with the official Business Enterprise R&D (BERD) data provided to the OECD by Member countries. To achieve this level of consistency, many of the data points have been estimated on the basis of additional information available in Member countries and through the use of pure statistical interpolation techniques (spline function). The first version of the database is described in OECD (1992c).

The database includes time-series data of sectoral intramural R&D expenditures for 22 ISIC manufacturing and several service sectors from 1973 to 1991, though this project does not use its services segment due to the underlining availability problems in several countries. This time series data set is currently available only in current prices. The countries currently covered are Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, the UK, and the US. Although an R&D stock variable is more appropriate to investigate the level of technological knowledge in industries, reliable data to construct this variable are not sufficiently provided, especially for sectoral R&D deflators and the rate of depreciation.

Input-Output tables

Input-output tables constitute the core data of the analysis. The OECD I/O database was originally developed to assist the OECD Industry Committee in making international comparisons of structural adjustment in industry (see OECD, 1992b). The database currently covers 10 OECD countries. The OECD input-output tables distinguish interindustrial flows of domestically produced and imported products (non-competing import type) and consist of the following five sub-matrices (Figures A.1, A.2):

- Domestic flows matrix (industry × industry)
- Imported flows matrix (industry × industry)
- Domestic investment flows matrix (industry × industry)
- Imported investment flows matrix (industry × industry)
- Value added components matrix (value added category × industry)

Except for the value added component matrix, these matrices are available in both current and constant price in national currency basis (the base-year of price deflators differs across the 10 countries). Industries are disaggregated into 36 ISIC sectors, of which the 22 manufacturing sectors are comparable with those of ANBERD and other databases (see Table A.1). Available years of the data are different by country, but typically contain three to five points of years, spanning from the early-1970s to the mid-1980s or to 1990 which allows a historical analysis of industrial structure (see table below).

The current sectoral disaggregation of the I-O database, however, has been suffering from several missing sectors for most countries which preclude exact sectoral comparison internationally. In particular, the extent of missing sectors is more serious in the disaggregation of investing industries (ie, column sectors) in capital flow matrices than in intermediate flows matrix across the countries (see Table A.2).

These missing sectors set a limit to establishing consistency between the databases in STAN. For example, other OECD data used in our analysis (R&D, employment and trade,etc) should be more aggregated by sector within a country, even though other data have complete sectoral profiles. For international comparisons, further aggregation must be made to keep sectoral consistency across the countries so that the original information can be lost in every step of such aggregation process.

Bilateral Trade Database

The bilateral trade database includes detailed trade flows for manufacturing industry from one country or geographical area to another. For each importing/exporting country, exports to and imports from the full list of partner countries or regions is provided (see OECD (1994a)). The data have been drawn from the foreign trade component of the OECD Statistics Directorate's COMTAP (Compatible Trade and Production) Database.

Industry coverage is 22 manufacturing sectors, following the same manufacturing classification as in used at input-output and ANBERD databases. The period covered spans from 1967 to 1992, providing manufacturing imports and imports in current US dollars of 14 OECD countries from and to the trading partners (14 OECD countries, the rest of OECD, 12 developing countries, and the rest of the world). In this project, trading partners were further aggregated for each of 10 OECD countries concerned into 12 trading partners or regions: other 9 OECD countries, the rest of the OECD, China plus the so-called Dynamic Asian Countries (Hong Kong, Malaysia, Singapore, South Korea, Thailand and Taiwan), and the rest of the world. The data were then combined with input-output database to generate regional distribution of exports and imports in input-output tables by those 12 regions.

NOTES

1. Levin *et al.* (1987) provide information based on evidence from surveys on the importance of various channels of knowledge transmission.

2. Research spillovers have been defined to include "any original, valuable knowledge generated in the research process which becomes publicly accessible, whether it be knowledge fully characterising an innovation, or knowledge of a more intermediate sort" (Cohen and Levinthal, 1989). Griliches (1993) and Nadiri (1993) provide surveys of the impact of research spillovers.

3. The aim was to link data on patents, which are function-oriented (*i.e.* they group inventions that employ similar engineering concepts or ideas), with data on economic variables, which are industry-oriented. To do so, they used the industry-of-origin (IIO) and industry-of-use (IOU) codes assigned to all Canadian patents in order to generate two concordances: one between the International Patent Classification (IPC) code and the industry of origin code and one between the IPC code and the industries of use codes. This makes it possible to obtain an estimate of the total number of patents (*i.e.* of technology flows) by origin and use in each industry.

4. DeBresson *et al.* (1994) found that their innovation matrix exhibits a pattern similar to that of intermediate flow (domestic and import requirements) input-output matrices. They concluded that input-output analysis is useful for identifying the location of economic activities in economic space and that the location of innovative activity is structured in a way that is statistically related to economic activity.

5. See for example Terleckyj, N. (1974), "Effects of R&D on the Productivity Growth of Industries: An Exploratory Study", (Washington D.C: National Planning Association); Scherer, F.M. (1982a), "Interindustry Technology Flows in the US", *Research Policy*, 11, pp. 227-245, March; Davis, A.L., (1988), "Technology Intensity of U.S., Canadian and Japanese Manufactures Output and Exports", U.S. Department of Commerce, International Trade Administration, June.

6. To illustrate the simplest version of the input-output scheme, assume that industry *i* undertakes $100 of R&D and sells $400 of output; $300 to industry *j* and $100 to industry *k*. As a first approximation, industry *j* is assumed to acquire $75 (ie $300/$400) of external technology from industry *i* and *k* to acquire $25. The assumption is that the "amount" of technology acquired is *proportional* to the quantity of goods purchased. Industry *i* itself however purchases some of the output of industries *j* and *k*, and this feedback loop, characteristic of input-output schemes, implies that industry *i*'s output embodies not only its own R&D but also some part of the R&D undertaken by industries *j* and *k*. Inversion of the input-output matrices captures the effects of this feedback loop and yields a consistent solution for the inter-industry flows of embodied technology. A fundamental conclusion is that the aggregate technological level of an economy, reflecting the total amount of technology in use by all industries, increases with increasing inter-industry linkages. With increasing technology diffusion industries benefit more from the R&D undertaken in other industries.

   Alternatively, it is possible to use R&D intensities rather than raw R&D expenditures (ie to normalise the technology flows by an industry's output. To illustrate the R&D intensity input-output scheme, assume that *j* is a second supplier industry which undertakes $150 of R&D and sells $300 of output; $100 to *i* and $200 to *k*. Each unit (dollar) of output of supplier industry *j* "embodies" $0.5 of its own R&D while that for *i* embodies $0.25 (ie $100/$400). These represent the own-R&D intensities of the supplier industries. Now assume that purchasing industry *k* in producing a unit of its own output uses \$0.3 of the output of *i* and \$0.1 of the output of *j*: these are the direct requirements coefficients for *k*. If *k* also itself undertakes \$0.2 of R&D per unit of its own output, then a first approximation of its total own-plus-embodied R&D per unit of output will be \$0.2+(\$0.25 x \$0.3)+(\$0.5 x \$0.1)=\$0.325. As in the case where R&D expenditures are used directly, there is an embodied R&D feedback loop and inversion of the input-output matrices yields a consistent and higher figure for the embodied R&D per unit of output of industry *k*. The total R&D intensity of industry *k* is thus a weighted sum of its own R&D intensity and the R&D intensities of the industries from which it purchases inputs.

7. The Leontief inverse matrix gives the total (direct and indirect) input requirements per unit of final demand. It is defined as $B=[b_{ij}]=(I-A)^{-1}$ in the solution to the system $X=(I-A)^{-1}Y$, where X is the vector of gross output by industry, I is the identity matrix, Y is the vector of final demands by industry, and A is the direct requirement matrix whose element a_{ij} is the quantity of output of sector *i* absorbed by sector *j* per unit of its output X_j, ie $a_{ij}=X_{ij}/X_j$. Thus the element b_{ij} of the Leontief inverse matrix B (also called a final demand-to-output multiplier) indicates by how much the output of industry *i* would need to increase in order to satisfy a one-unit increase of the *final demand* of industry *j* (Y_j). Since the output of industry *j* increases by more than one-unit in this propagation process, this matrix is applicable for the calculation of investment-based R&D indicators, but not suitable for defining the R&D contained in the output of industry *j*. In order to avoid overestimation of the R&D content of industry *j* as well as to clearly separate the direct and indirect R&D content, a modified version of the Leontief inverse matrix is calculated for this project, whose element b^*_{ij} indicates by how much the output of industry *i* would need to increase in order to satisfy a one-unit increase of the *gross output* of industry *j* (X_j) -- an output-to-output multiplier. See Leontief, W. (1986), *Input-Output Economics*, Oxford University Press, Ch.2, and Miller, R. and Blair, P. (1985), *Input-Output Analysis: Foundations and Extensions*, Prentice-Hall, p.328.

8. Thus, if the French car industry imports steel from Germany and the UK, the R&D intensity of the imported steel used for the construction of cars in France will be the sum of the German steel R&D intensity weighted by the share of steel imports from Germany in total steel imports of the French car industry and the corresponding figures for the UK.

9. These assumptions are discussed in more detail in OECD (1992), *Structural Change and Industrial Performance*, OECD Document Series.

11. The reader is alerted to the fact that despite substantial efforts to make input-output tables fully comparable across countries, some comparability problems remain and are likely to influence the results. Thus, the government producers sector is separately identified in most but not all countries (France, Japan, Germany, Canada, Australia, Denmark, the Netherlands). The same is true for some countries for an industry category called other producers.

12. According to the survey done by BLS (1989), Terleckyj (1974) reported separate significant effects for research contained in capital and research contained in materials for manufacturing industries; however, the capital effect was very much greater. In non-manufacturing, research embodied in materials had an effect but, surprisingly, research contained in capital did not. Subsequently, Sveikauskas (1981) and the regressions based on the largest sample in Scherer (1982b) report extremely high returns for purchased capital, but none for intermediate inputs (materials), yet other regressions in Scherer's work find significant positive effects for purchase of research through materials. Moreover, Griliches and Lichtenberg (1984) conclude that the influence of R&D embodied in purchases from other sectors is

"weak and unstable over time". Finally, Terleckyj (1984) dropped out the research-through-capital variable once an industry's own research was introduced.

13. For example, a 68% of investment done by the US communications sector in 1990 was the purchase of communication equipment and semiconductors, while the percentage was only 12.6% for the industries as a whole. Although the level of this share is much lower than the US, the purchase of information components in communication investment also constituted a large portion in other countries (43% in France, 40% in Italy, 38% in Japan).

14. The share of capital-embodied R&D in total acquired technology for the entire services sector (including utilities and construction) has increased by 9.1 percentage points for the US (1982-90), 12.5 for Japan (1980-90), 2.7 for Germany (1978-86), 3 for France (1977-85), 2.7 for the UK (1979-84), 4.9 for Canada (1981-90), 4.4 for the Netherlands (1977-86) and 6.3 for Denmark (1977-90).

15. See for example papers in OECD (1993) *STI Review* No. 13.

16. The Spearman's rank correlation coefficient between the size of the economy and the share of acquired technology obtained from imports is 0.94. The 1991 ranking of the ten countries, on the basis of billions of US dollar purchasing power parities (PPPs) is: 1) US (5 610); 2) Japan (2 349); 3) Germany (1 344); 4) France (1 036); 5) Italy (974); 6) the UK (900); 7) Canada (521); 8) Australia (285); 9) the Netherlands (248); and 10) Denmark (91).

17. Exceptions include computers and office equipment in Japan and aerospace in the US.

18. The major shortcomings underlying the technology indicators are documented in the methodological section in the main text.

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Figure 1: Sources of technology embodied in output

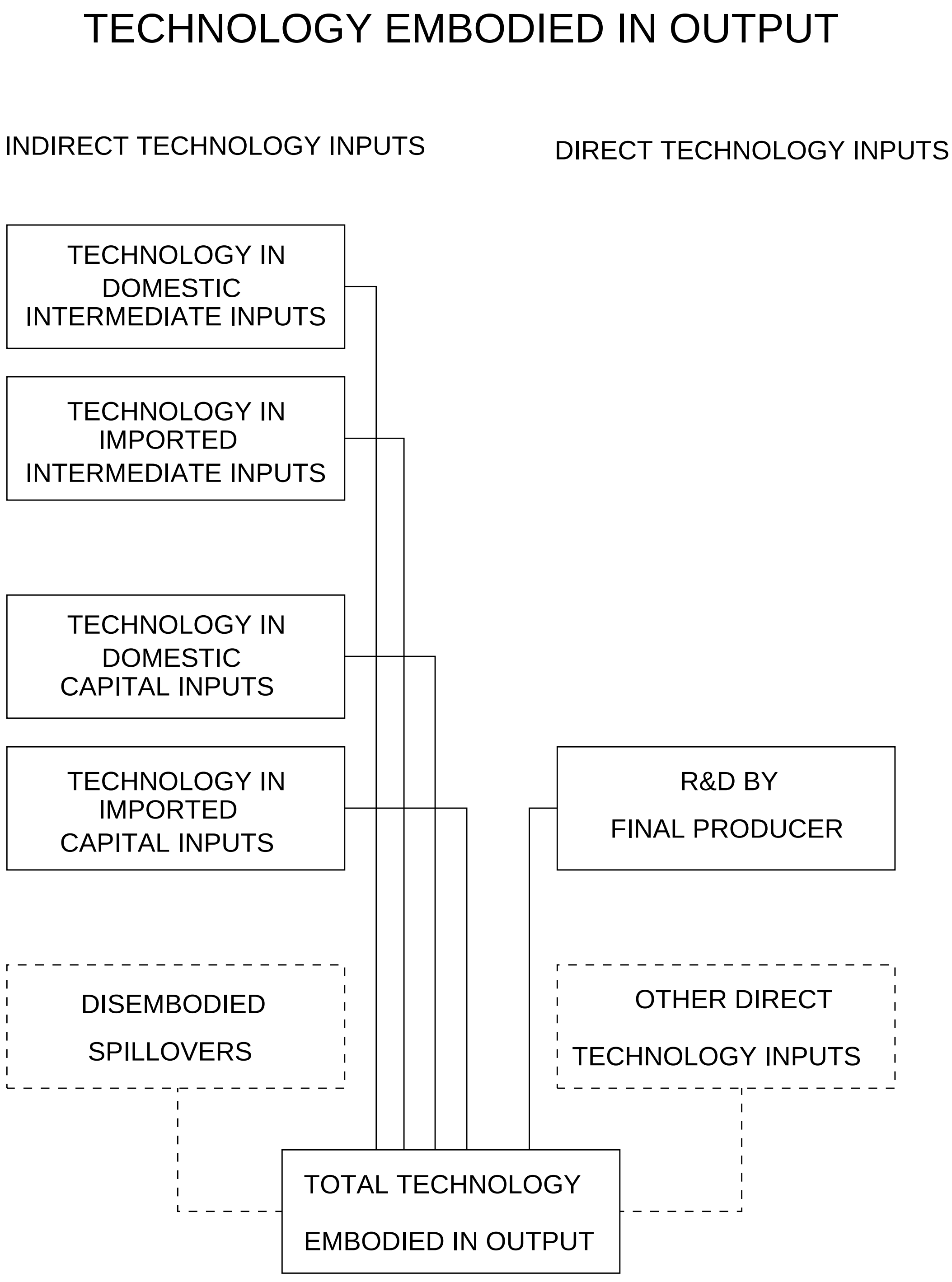
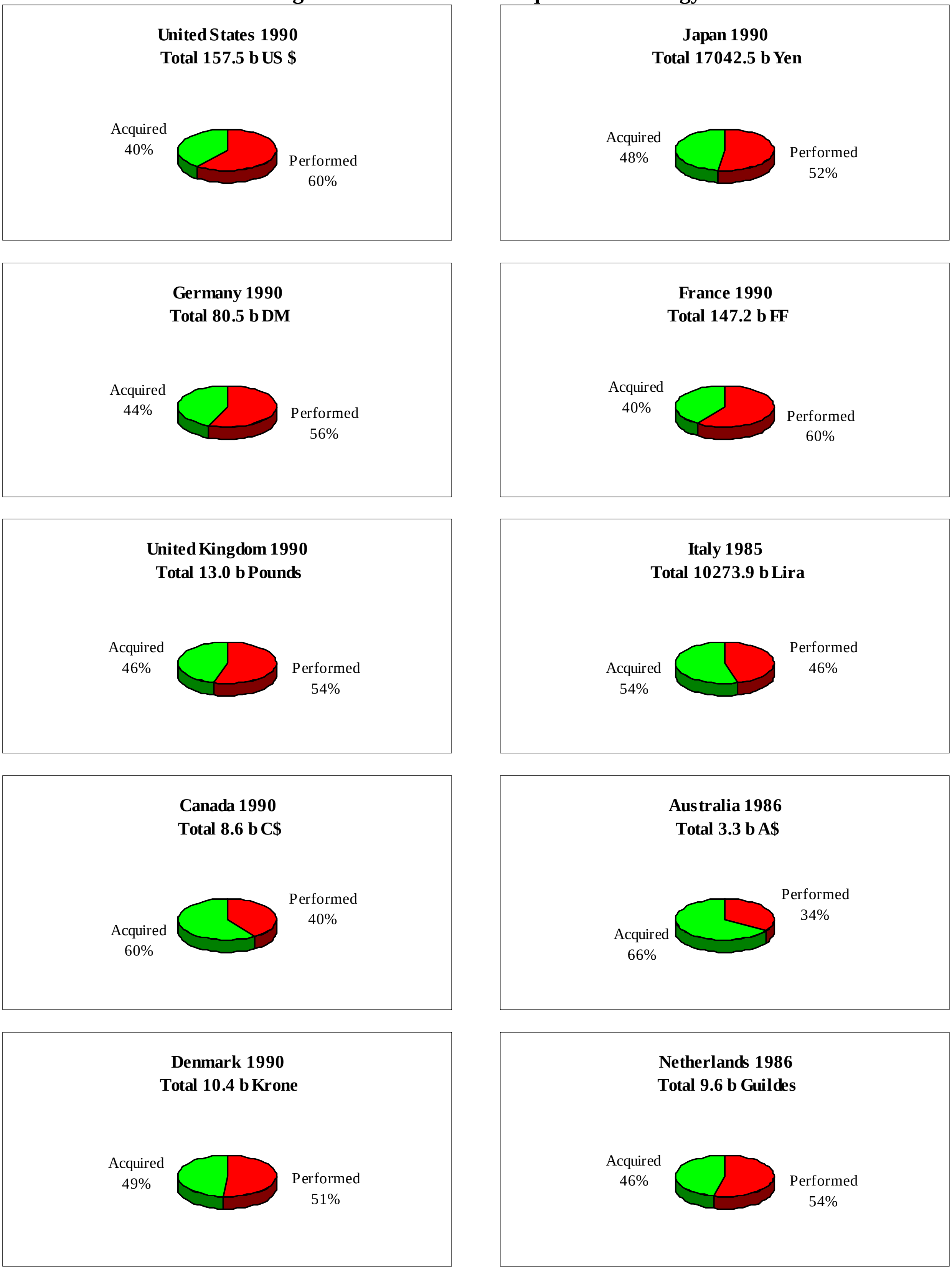


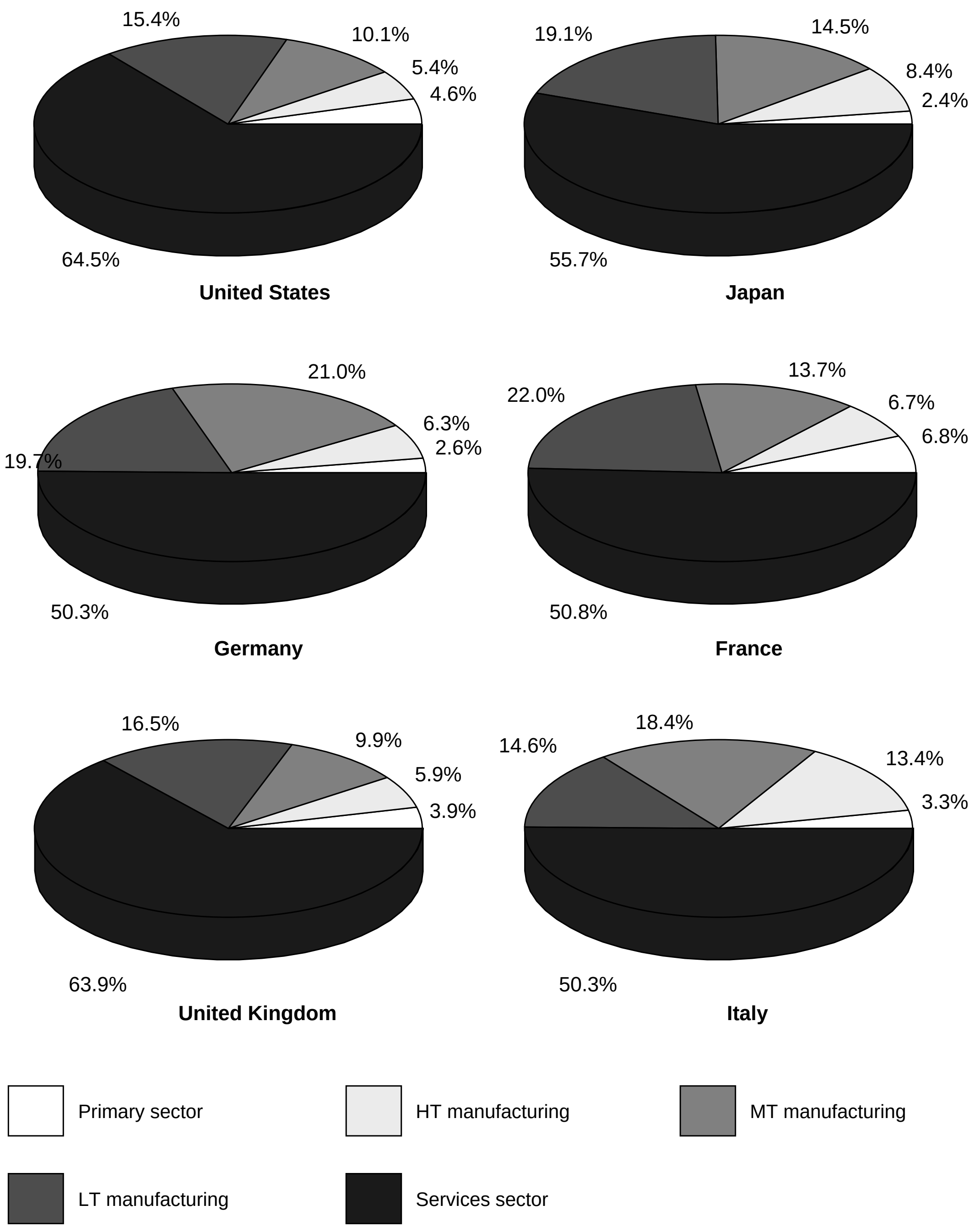
Figure 2. Performed vs. acquired technology



Source: OECD input-output database; DSTI/EAS Division.

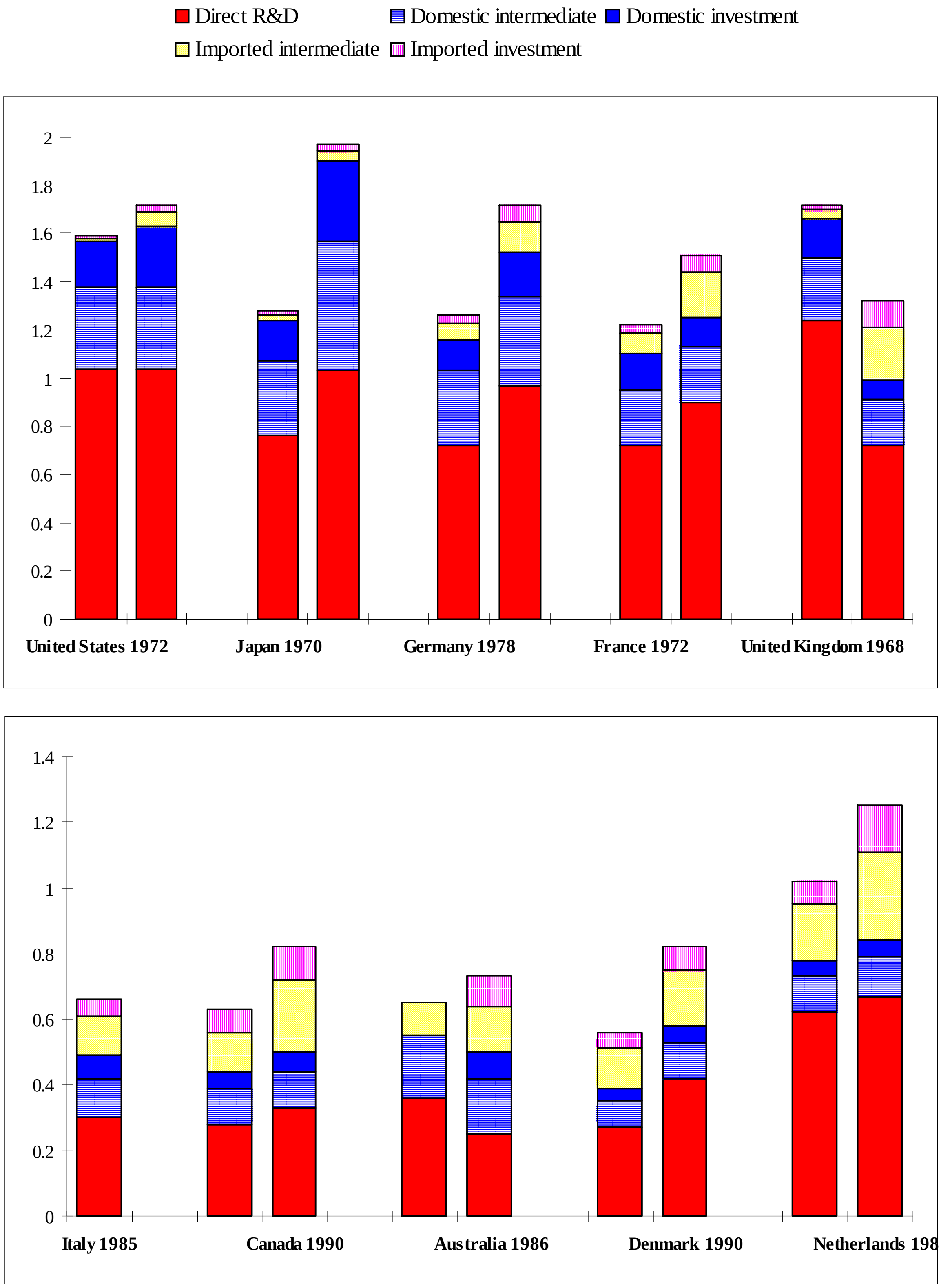
Figure 2a. Technology use

Acquired technology by user sector



OECD STAN input-output database.

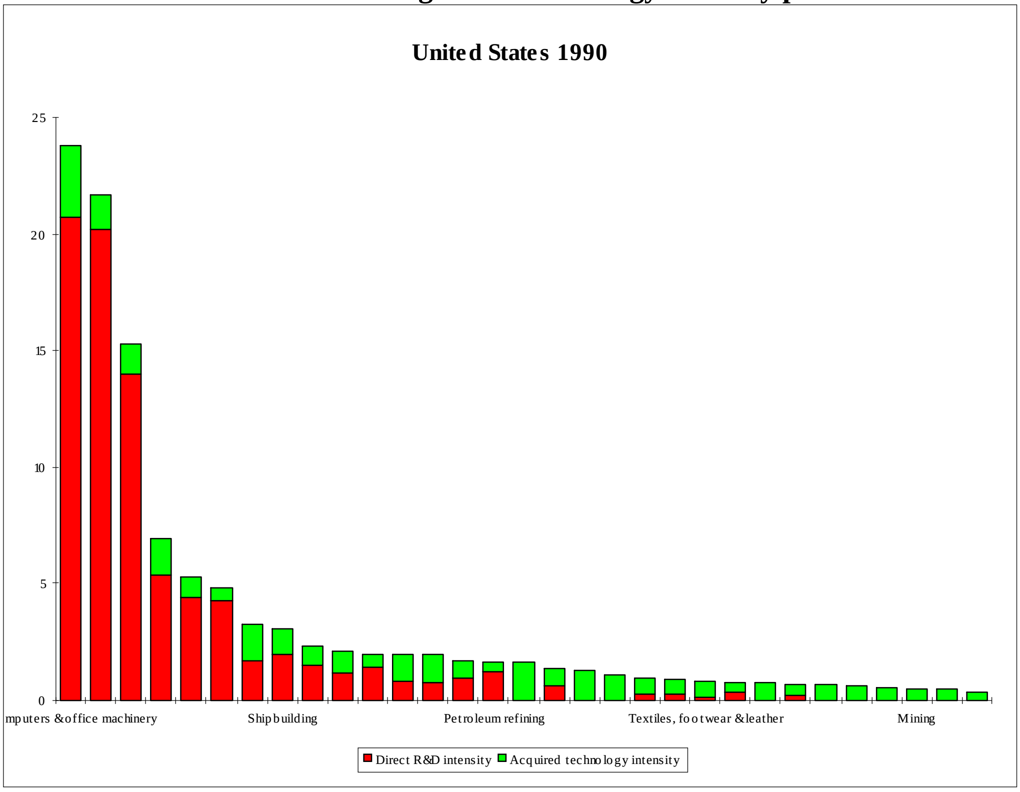
Figure 3. Total technology intensities

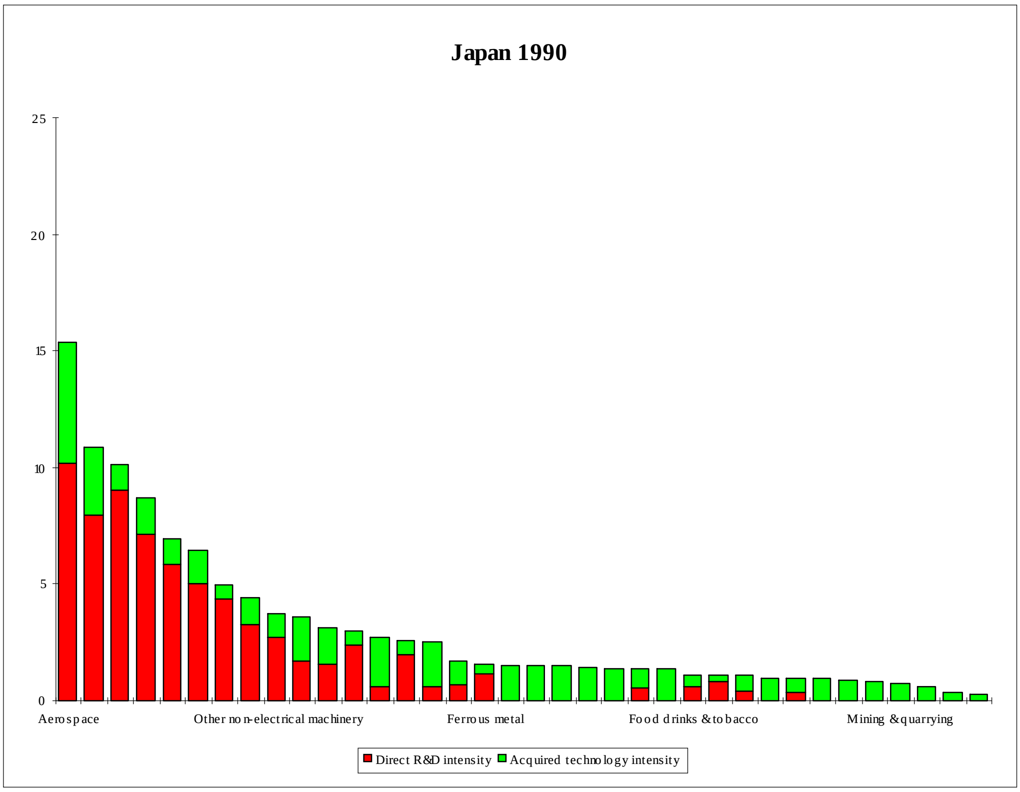


Source : OECD, STAN Input-Output database.

Source: OECD input-output database; DSTI/EAS Division.

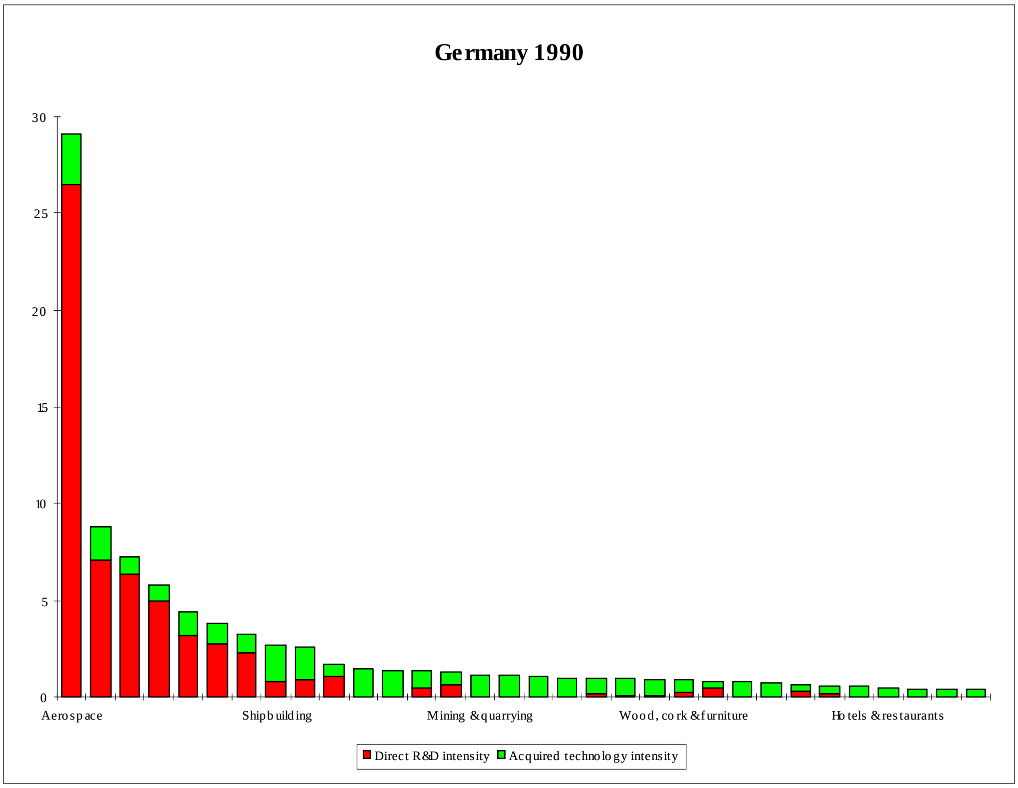
Figure 4. Technology intensity profiles

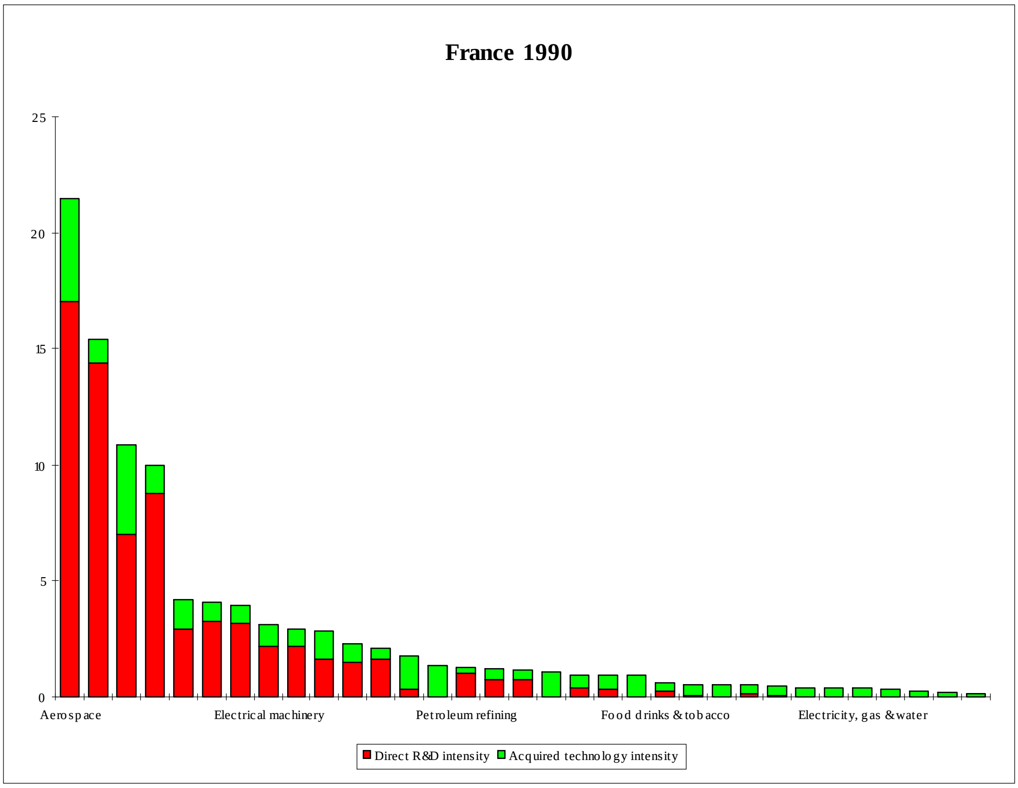




Source: OECD input-output and ANBERD databases; DSTI/EAS Division.

Figure 4 (cont.). Technology intensity profiles





Source: OECD input-output and ANBERD databases; DSTI/EAS Division.

Figure 5. Share of total acquired technology obtained through investment goods purchases (Total enterprise sector)

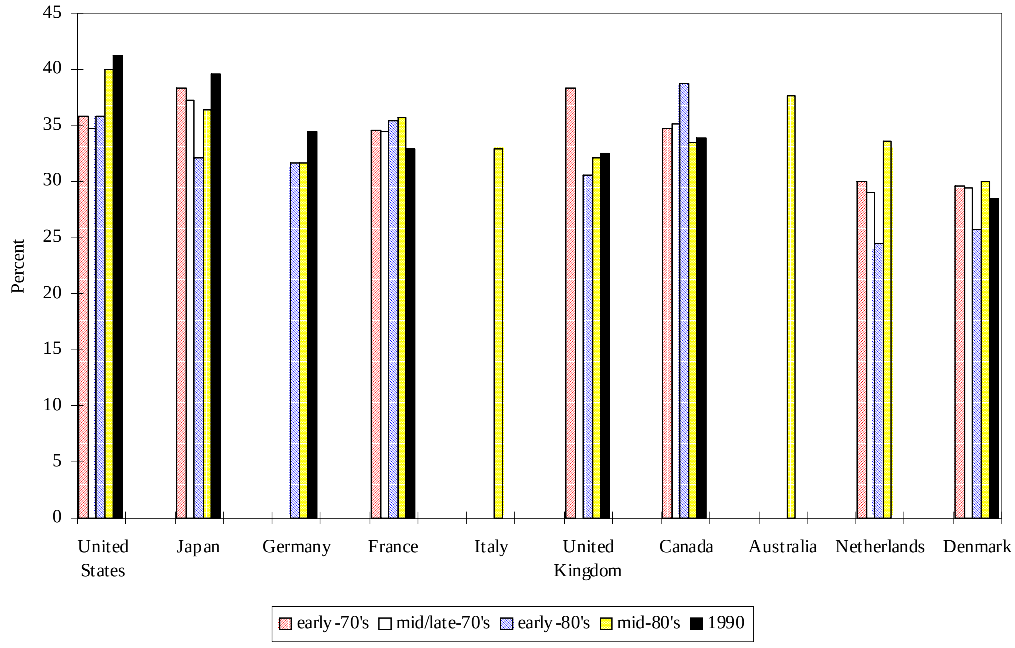
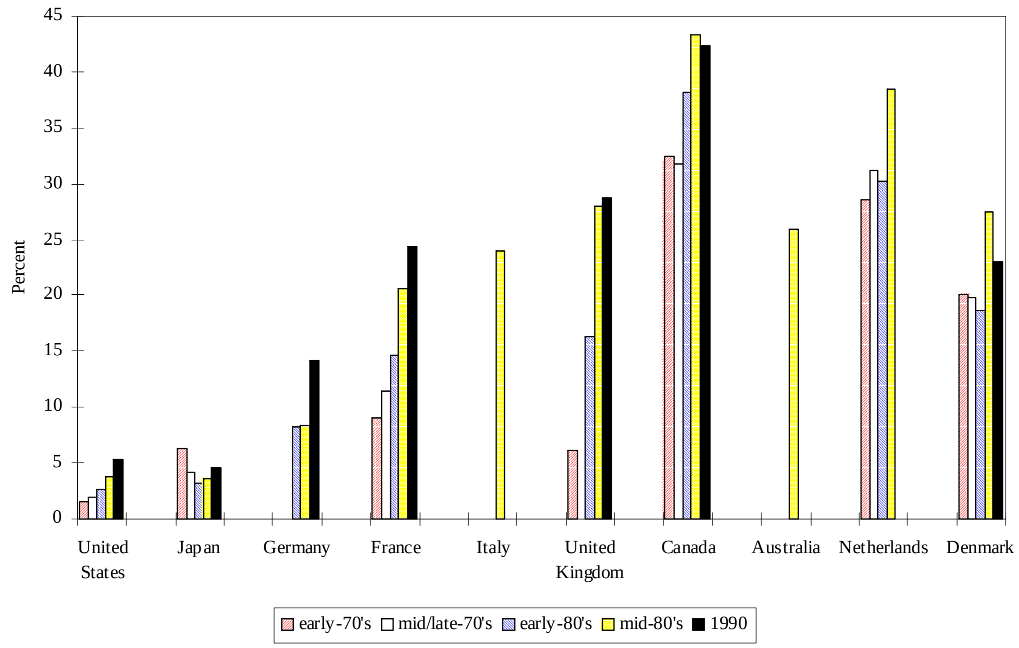
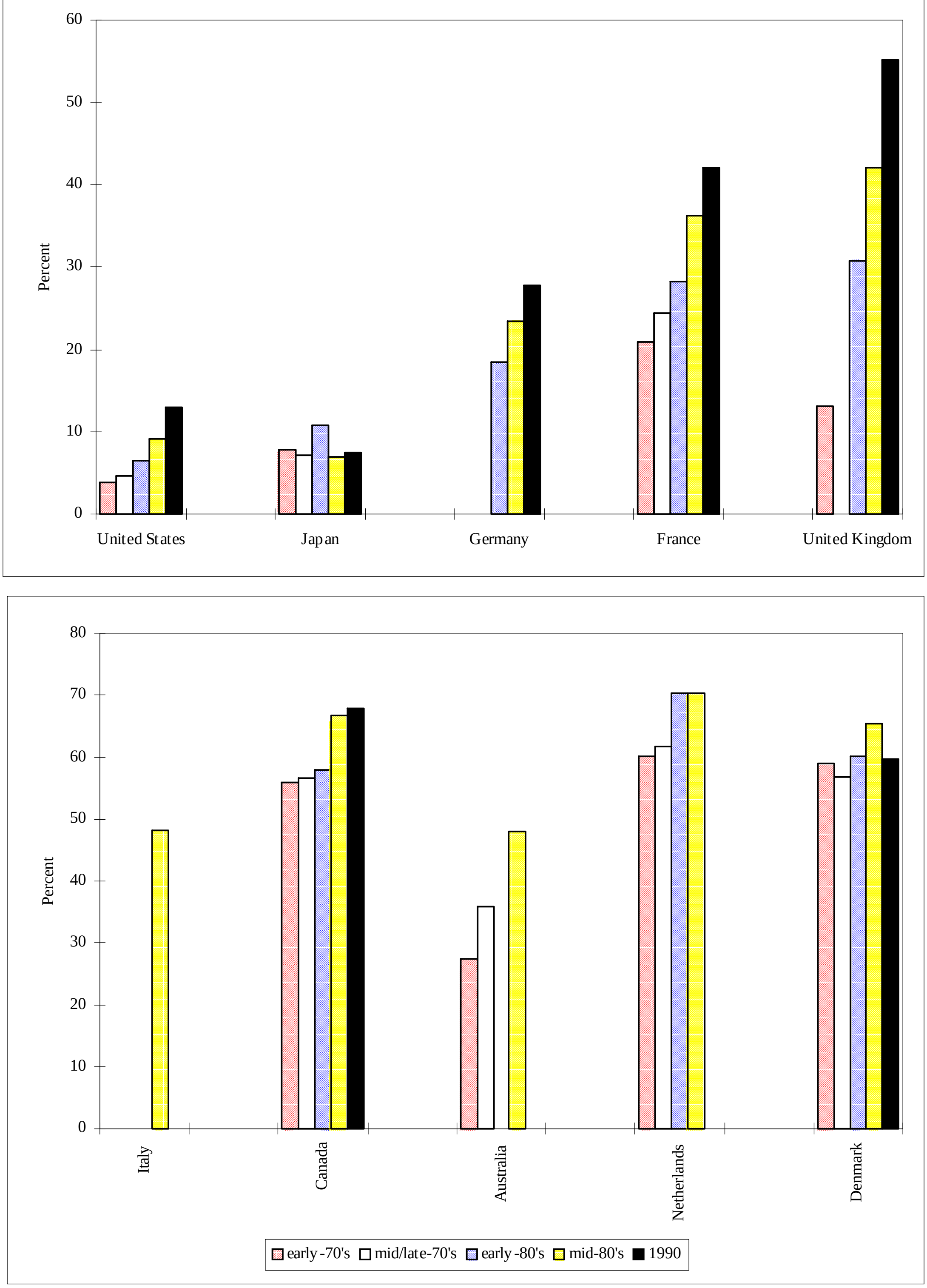


Figure 6. Share of total acquired technology obtained through imported investment goods (Total private services)



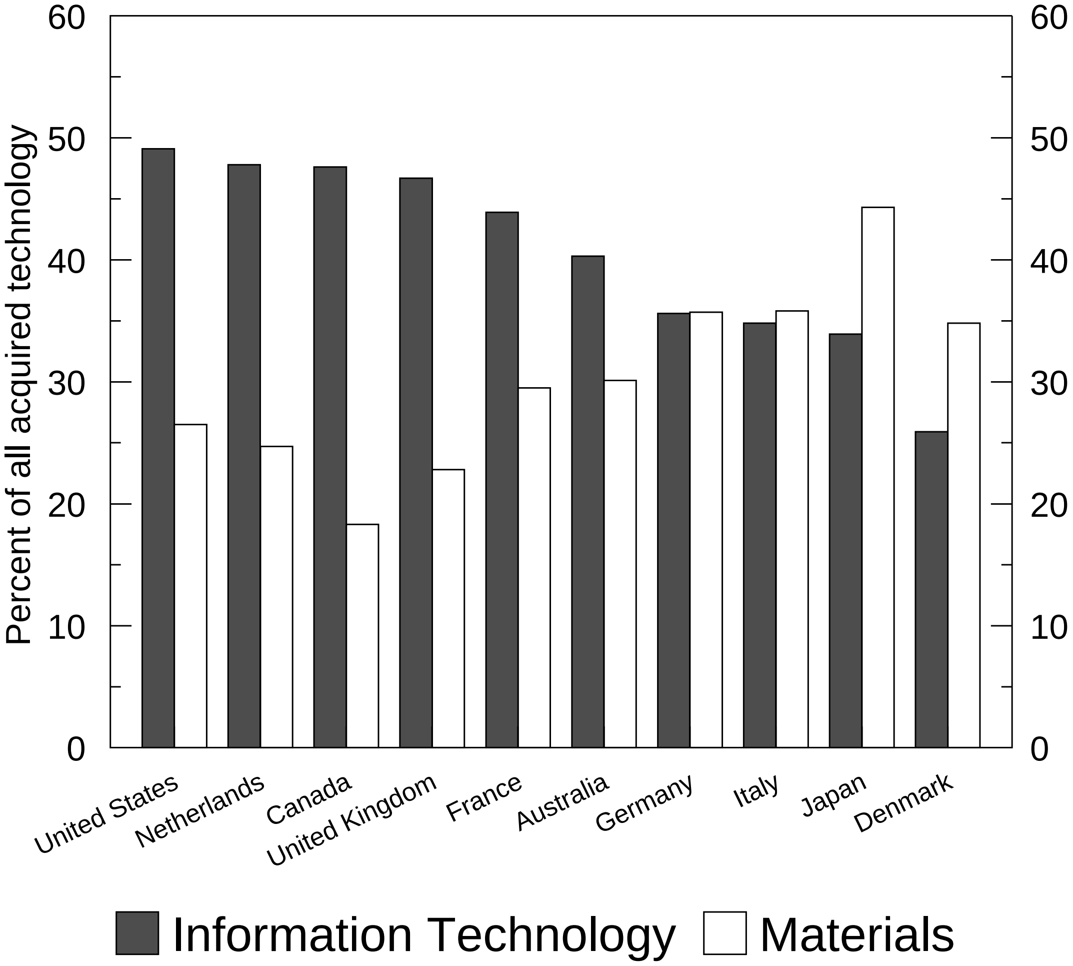
Source: OECD input-output and ANBERD databases; DSTI/EAS Division.

Figure 7. Share of total acquired technology obtained from imports (Total enterprise sector)



Source: OECD input-output and ANBERD databases; DSTI/EAS Division.

Figure 8. Share of acquired technology from information technology and materials



Source: OECD STAN Input-Output database.

Figure A.1. Input-output system

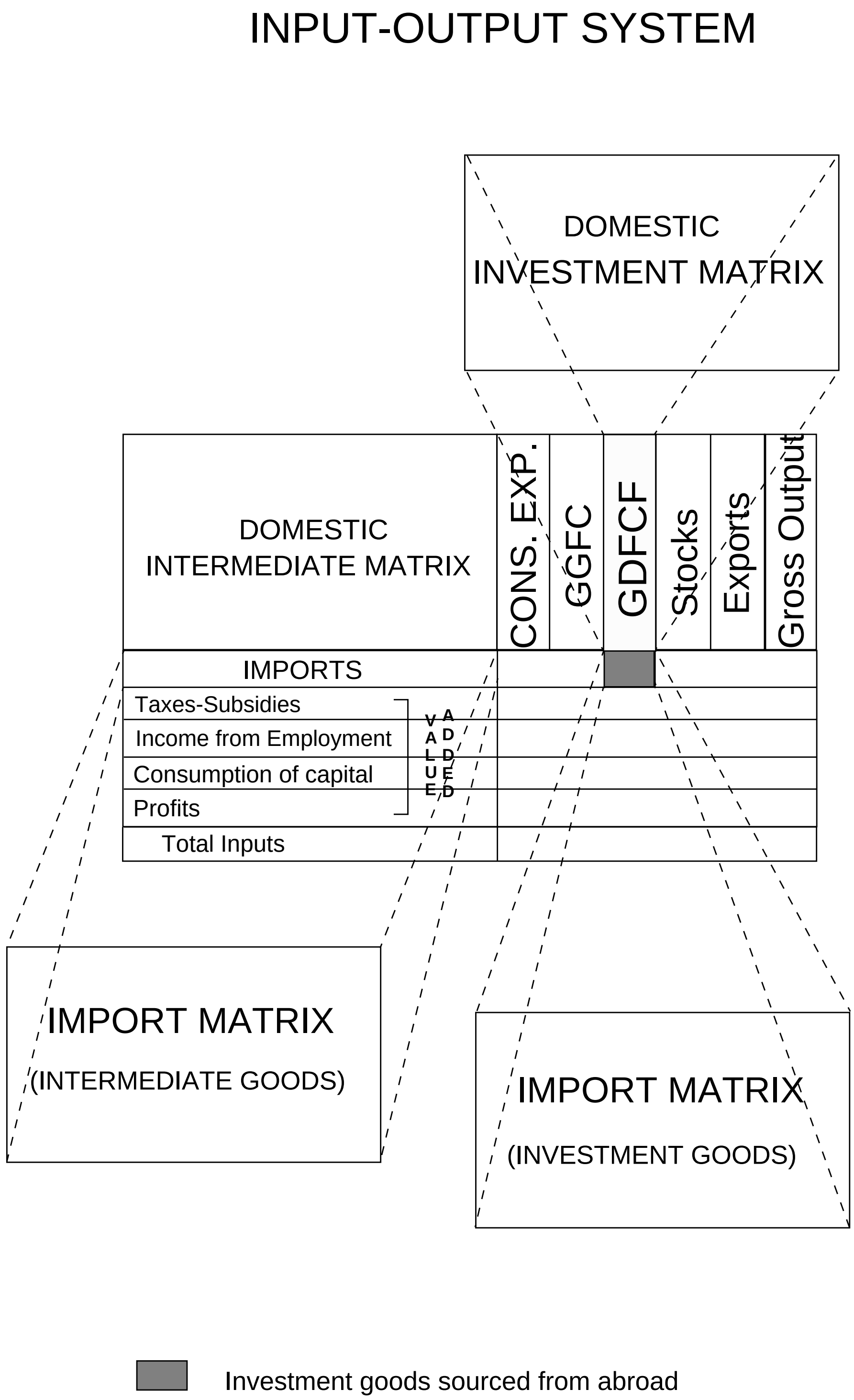


Figure 2: Sectoral Format of OECD's Input-Output Database (competing import form)

No.	ISIC codes	Description	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 32 34 35 36	37 38 39 40 41 42 43 44 45
1	1	Agriculture, forestry and fishing		
2	2	Mining	Intermediate consumption	Final demand
3	31	Food, drink & tobacco		
4	32	Textiles, footwear & leather		
5	33	Wood, cork & furniture		
6	34	Paper & printing		
7	351+352-3522	Chemicals		
8	3522	Pharmaceuticals		
9	353+354	Petroleum refining		
10	355+356	Rubber & plastics		
11	36	Stone, clay & glass		
12	371	Ferrous metals		
13	372	Non-ferrous metals		
14	381	Fabricated metal products		
15	382-3825	Other non-electrical machinery		
16	3825	Computers & office machinery		
17	383-3832	Electrical machinery		
18	3832	Communications & semiconductors		
19	3841	Shipbuilding		
20	3842+3844+3849	Other transport		
21	3843	Motor vehicles		
22	3845	Aerospace		
23	385	Instruments		
24	39	Other manufacturing		
25	4	Electricity, gas and water services		
26	5	Construction		
27	61+62	Wholesale & retail trade		
28	63	Hotels & Restaurants		
29	71	Transport & storage		
30	72	Communications		
31	81+82	Finance & insurance		
32	83	Real estate & other business services		
33	9	Social & personal services		
34		Government producers		
35		Other producers		
36		Statistical discrepancy		
37		**Total intermediate inputs**		
38		Taxes less subsidies		
39		Income from employment		
40		Profits and income from property		
41		Depreciation of fixed capital		
42		**Total industry output**		

Explanation of columns

Col No.	Description	Col No.	Description
1-36	Identical to rows 1-36	41	Changes in stocks
37	Total of intermediate demand	42	Exports of goods and services
38	Private domestic consumption	43	**Total final demand**
39	Government consumption	44	Imports of goods and services (negative)
40	Gross domestic fixed capital formation	45	**Total industry output**

Table1. R&D expenditures and embodied technogy

		Direct manufacturing R&D expenditures	Estimated indirect technology embodied in gross output	Technology multiplier (Total/direct)
United States (Million US$)				
	1972	20535	31495	1.5
	1977	28867	47933	1.7
	1982	56178	93876	1.7
	1985	77525	127338	1.6
	1990	95086	157465	1.7
Japan (Billion Yen)				
	1970	1235	2076	1.7
	1975	1589	3208	2.0
	1980	2984	6076	2.0
	1985	5722	10808	1.9
	1990	8901	17043	1.9
Germany (Million DM)				
	1978	18381	31931	1.7
	1986	36276	61554	1.7
	1990	45401	80456	1.8
France (Million FF)				
	1972	10747	18152	1.7
	1977	18604	33537	1.8
	1980	28650	51229	1.8
	1985	57639	102748	1.8
	1990	87690	147232	1.7
United Kingdom (Million GBP)	1968	899	1246	1.4
	1979	2706	4443	1.6
	1984	4293	7227	1.7
	1990	7079	13031	1.8
Italy (Billion Lira)				
	1985	4705	10274	2.2
	1990	8864	..	..
Canada (Million C$)				
	1971	421	935	2.2
	1976	601	1580	2.6
	1981	1693	4266	2.5
	1986	2703	6959	2.6
	1990	3475	8624	2.5
Australia (MIllion A$)				
	1968	190	346	1.8
	1974	192	440	2.3
	1986	1132	3331	2.9
	1990	1101	..	..
Denmark (Million Krone)				
	1972	634	1304	2.1
	1990	5335	8588	1.6
	1972	1669	2749	1.6
	1986	5131	9586	1.9
	1990	5335	10446	2.0
Netherlands (Million Guilders)				
	1972	1669	2749	1.6
	1977	2410	4192	1.7
	1981	3162	5941	1.9
	1986	5131	9586	1.9

Source: OECD Input-Output database; ANBERD database; DSTI/EAS Division.

Table 2. R&D performance and technology use in 1990: five biggest industries in 10 OECD countries (1)

		United States				Japan	
Performers	**Share**	**Users**	**Share**	**Performers**	**Share**	**Users**	**Share**
Aerospace	26.7	Social & personal services	12.5	Communications equipment	16.3	Social & personal services	11.5
Communications equipment	16.8	Wholesale & retail trade	9.9	Motor vehicles	14.4	Construction	10.8
Chemicals	13.2	Real estate & bus. services	7.6	Electrical machinery	11.2	Real estate & bus. services	10.0
Computers	12.5	Transport & storage	7.1	Chemicals excl. pharm.	10.1	Transport & storage	8.6
Motor vehicles	10.6	Construction	6.4	Computers	10.1	Motor vehicles	6.0
		Germany				**France**	
Performers	**Share**	**Users**	**Share**	**Performers**	**Share**	**Users**	**Share**
Electrical machinery **	26.4	Motor vehicles	10.2	Communications equipment	23.8	Aerospace	10.4
Chemicals *	22.0	Real estate & business services	9.1	Aerospace	20.6	Transport & storage	10.2
Motor vehicles	17.6	Transport & storage	6.9	Motor Vehicles	12.4	Construction	7.1
Other non-electrical	10.8	Other non-electrical machinery	6.8	Chemicals excl. pharm.	10.0	Motor vehicles	6.1
Aerospace	9.1	Construction	6.3	Pharmaceuticals	8.0	Social & personal services	5.8
		United Kingdom				**Italy**	
Performers	**Share**	**Users**	**Share**	**Performers**	**Share**	**Users, 1985**	**Share**
Communications equipment	22.9	Social & personal services	14.8	Motor Vehicles	18.4	Social & personal services	18.1
Pharmaceuticals	16.3	Aerospace	8.1	Communications equipment	14.3	Transport & storage	7.2
Aerospace	15.9	Real estate & business services	7.8	Pharmaceuticals	14.1	Construction	6.2
Chemicals excl. pharm.	11.4	Wholesale & retail trade	7.3	Aerospace	11.7	Chemicals excl. pharm.	5.3
Computers	8.6	Finance & insurance	6.7	Electrical machinery	8.4	Real estate & bus. services	5.0
		Canada				**Australia**	
Performers	**Share**	**Users**	**Share**	**Performers**	**Share**	**Users, 1986**	**Share**
Communications equipment	32.5	Motor vehicles	15.9	Communications equipment	15.0	Finance & insurance	15.3
Aerospace	13.2	Communications equipment	8.7	Motor vehicles	12.2	Construction	14.4
Computers	8.6	Communications services	8.7	Communications services	10.2	Wholesale & retail trade	9.7
Pharmaceuticals	7.4	Social & personal services	8.7	Iron & Steel	10.2	Social & personal services	9.8
Chemicals excl. pharm.	4.8	Transport & storage	8.5	Chemicals excl. pharm.	10.0	Fabricated metals	7.7
		Denmark				**Netherlands**	
Performers	**Share**	**Users**	**Share**	**Performers**	**Share**	**Users**	**Share**
Pharmaceuticals	23.8	Transport & storage	12.8	Chemicals excl. drugs	27.5	Electrical machinery **	13.2
Non-electrical machinery	15.6	Chemicals *	11.4	Electrical machinery	19.8	Chemicals excl. pharm.	8.9
Sc. instruments	11.5	Construction	10.0	Communications equipment	16.2	Social & personal services	6.8
Communications equipment	9.9	Agriculture	9.1	Pharmaceuticals	8.5	Construction	6.5
Other Manufacturing, nec	8.3	Non-electrical machinery	7.9	Food/beverages/tobacco	5.3	Transport & storage	6.3

1. The shares of R&D performers are in total manufacturing R&D (except for Australia, where they also cover services R&D); the share of technology use is calculated in the total idirect tcehnology embodied in output.

*: includes pharmaceuticals.

**: includes communications equipment

Source: OECD STAN Input-Output database; DSTI/EAS Division.

Table 3. The technology content of production

	United States 1990	Japan 1990	Germany 1990	France 1990	United Kingdom 1990	Italy 1985	Canada 1990	Australia 1986	Netherlands 1986
Primary sector	74	98	141	84	69	73	46	115	77
Manufacturing sector	121	104	115	135	132	112	148	117	160
High tech manufacturing	244	167	149	332	340	322	541	210	456
Aerospace	218	552	239	774	647	902	570	632	1397
Computers *	443	310	236	682	522	727	1386	..	403
Communications equipment	192	116	..	179	276	461	786	263	
Pharmaceuticals	..	117	..	206	98	303	131	135	366
Electrical machinery	230	152	122	165	158	110	117	186	388
Scientific instruments	235	161	144	129	211	172	225	194	329
Medium tech manufacturing	114	119	141	136	121	160	193	152	222
Motor vehicles	126	123	163	139	142	161	326	170	372
Chemicals **	78	62	107	147	120	166	104	246	184
Low tech manufacturing	82	66	76	68	64	57	46	90	76
Private services	92	97	84	76	86	93	78	99	64
Electricity, gas & water	159	159	155	69	78	73	136	21	107
Construction	92	99	98	72	42	94	57	151	83
Wholesale & retail trade	66	39	52	36	66	37	22	72	40
Transport & storage	184	148	188	194	79	175	154	105	134
Communication	235	160	200	237	261	424	423	123	113
Finance & insurance	94	31	50	20	90	42	17	241	18
Real estate & business services	51	91	53	70	85	67	48	34	27
Social & personal services	108	162	130	79	120	130	148	143	78

* Includes communications equipment for Germany; includes el. machinery for France.

** Includes pharmaceuticals in the case of the US, Germany.

1. This index is calculated as the ratio of the share of technology acquired by each industry in the total embodied technology in the economy to the corresponding share in production. A value of 100 means that an industry's weight in technology acquisitions is the same as its share in production.

Source: OECD input-output database; DSTI/EAS Division.

Table 4. Direct and total technology intensities for high, medium and low technology manufacturing industries

	Direct R&D intensities			Total technology intensities		
	High technology industries	Medium technology industries	Low technology industries	High technology industries	Medium technology industries	Low technology industries
United States 1990	12.3	3.0	0.5	13.9	3.7	1.0
Japan 1990	6.4	3.0	0.8	7.9	4.1	1.4
Germany 1990	7.3	2.8	0.4	8.4	3.8	0.9
France 1990	9.5	2.3	0.4	11.4	3.2	0.8
United Kingdom 1990	9.0	1.9	0.3	11.1	2.7	0.7
Italy 1985	4.2	0.9	0.1	5.4	1.5	0.3
Canada 1990	6.7	0.6	0.3	9.4	1.6	0.5
Australia 1986	5.0	1.2	0.2	6.1	1.8	0.5
Denmark 1990	8.0	2.2	0.3	9.2	3.0	0.7
Netherlands 1986	8.9	2.5	0.3	11.5	3.8	0.7

Source: OECD STAN Input-Output database; ANBERD database; DSTI/EAS Division.

Table 5. The five Industries most dependent on investment-based technology acquisition

		Share of obtained investment	Share of in total private investment			Share of obtained investment	Share of in total private investment
USA	1Finance & insurance	85.7	6.5	**UK**	1Finance & insurance	80.5	10.6
1990	2Electricity, gas & water	75.5	9.8	**1990**	2Communication	75.8	5.7
	3Communication	74.9	4.3		3Real estate & business	72.7	13.2
	4Transport & storage	70.5	8.2		4Transport & storage	56.5	6.5
	5Wholesale & retail trade	62.9	17.8		5Petroleum refining	54.1	1.2
Japan	1Communication	94.3	2.7	**Canada**	1Electricity, gas & water	91.8	8.9
1990	2Electricity, gas & water	84.3	9.2	**1990**	2Communication	91.0	4.5
	3Real estate & business	83.3	19.8		3Real estate & business	86.3	5.9
	4Finance & insurance	69.2	1.7		4Social & personal	84.7	7.9
	5Petroleum refining	67.4	0.5		5Hotels & restaurants	71.1	1.5
German	1Communication	85.8	4.4	**Australia**	1Finance & business	69.8	19.2
1990	2Transport & storage	61.8	5.9	**1986**	2Transport & storage	64.0	11.4
	3Finance & insurance	61.5	2.6		3Wholesale & retail trade	58.8	15.3
	4Electricity, gas & water	59.2	5.6		4Basic metal products	54.8	4.3
	5Wholesale & retail trade	58.0	6.8		5Mining	49.5	9.2
France	1Finance & insurance	88.0	2.7	**Netherla**	1Communication	81.9	2.4
1990	2Communication	82.5	2.7	**1986**	2Transport & storage	75.9	8.2
	3Transport & storage	71.1	7.5		3Wholesale & retail trade	75.5	7.0
	4Social & personal	68.5	41.6		4Real estate & business	74.1	23.8
	5Hotels & restaurants	64.9	2.8		5Electricity, gas & water	69.8	5.2
Italy	1Communication	93.1	3.5	**Denmark**	1Mining	74.4	1.5
1985	2Finance & insurance	86.2	1.8	**1990**	2Finance & insurance	73.4	1.9
	3Real estate & business	78.7	30.9		3Communication	72.8	3.2
	4Petroleum refining	77.5	3.4		4Electricity, gas & water	66.6	7.5
	5Wholesale & retail trade	73.7	6.5		5Transport & storage	61.1	15.2

Table 6. The five Industries least dependent on investment-based technology acquisition

		Share of obtained investment	Share of in total private investment			Share of obtained investment	Share of in total private investment
USA	1Other Transport	7.2	0.1	**UK**	1Computers & office	1.8	0.2
1990	2Computers & office	8.0	0.5	**1990**	2Aerospace	1.8	0.4
	3Aerospace	9.0	0.6		3Communication	5.6	0.9
	4Motor vehicles	9.3	1.6		4Rubber & plastic	6.1	0.6
	5Rubber & plastic	10.4	1.1		5Instruments	7.7	0.2
Japan	1Aerospace	3.7	0.0	**Canada**	1Shipbuilding	0.7	0.0
1990	2Other Transport	8.0	0.1	**1990**	2Communication	1.5	0.2
	3Construction	9.6	2.2		3Computers & office	1.7	0.1
	4Communication	11.2	1.0		4Aerospace	1.7	0.2
	5Rubber & plastic	13.7	1.0		5Motor vehicles	2.0	1.1
German	1Aerospace	7.2	0.2	**Australia**	1Electricity, gas & water	5.5	0.2
1990	2Shipbuilding	8.6	0.1	**1986**	2Construction	10.7	5.9
	3Rubber & plastic	11.8	1.1		3Chemicals, oil & coal	13.6	2.6
	4Construction	12.7	1.6		4Fabricated metal and	14.7	2.6
	5Non-ferrous metals	14.8	0.3		5Transport equipment	21.8	4.1
France	1Aerospace	2.5	0.6	**Netherla**	1Aerospace	2.5	0.1
1990	2Shipbuilding	6.0	0.1	**1986**	2Computers & office	4.2	0.1
	3Other non-electrical	8.9	1.1		3Shipbuilding	5.1	0.2
	4Communication	10.3	0.6		4Instruments	5.2	0.1
	5Motor vehicles	12.4	1.8		5Other manufacturing	8.2	0.1
Italy	1Aerospace	1.9	0.1	**Denmark**	1Transport mach. &	7.6	0.8
1985	2Computers & office	2.5	0.2	**1990**	2Electrical machinery	8.7	0.8
	3Communication	3.4	0.5		3Non-electrical equipment	10.3	2.2
	4Pharmaceuticals	6.8	0.3		4Chemicals	12.5	2.7
	5Other non-electrical	9.1	1.4		5Social & personal	13.9	1.3

Source: OECD input-output database; DSTI/EAS Division.

Table 7. Primary sectors responsible for the change in the import share of acquired technology

Country	Total Share Change (points)	Primary Sectors Responsible (points)		Share of Acquired Technology via Imports from Key Country of Origin	
Canada (1971-1990)	11.0	5.4	Social & personal services	78	USA
		5.1	Communication & semiconductors	73	USA
		2.1	Computers & office machinery	77	USA
Denmark (1972-1990)	0.8	2.1	Non-electrical equipment	26	GER
		2.1	Chemicals	30	ROO
		0.8	Fabricated metal	29	ROO
France (1972-1990)	18.0	2.8	Computers & electrical machinery	31	USA
		2.7	Aerospace & shipbuilding	49	USA
		2.7	Transport & storage	49	USA
Germany (1978-1990)	8.8	1.3	Transport & storage	45	FRA
		1.2	Motor vehicles	32	ROO
		0.7	Electrical machinery	24	ROO
Japan (1970-1990)	-0.3	0.9	Electrical machinery	62	USA
		0.7	Real estate & business services	74	USA
		0.1	Communication	61	USA
Netherlands (1972-1986)	10.4	2.4	Chemicals	34	GER
		1.9	Electrical machinery	28	GER
		1.4	Social & personal services	26	GER
United Kingdom (1968-1990)	42.2	6.8	Aerospace	63	ROW
		4.9	Social & personal services	23	USA
		4.6	Real estate & business services	25	ROW
United States (1972-1990)	9.1	1.1	Social & personal services	30	JPN
		1.0	Communication & semiconductors	38	DAE
		0.9	Computers & office machinery	45	DAE

Source: OECD input-output database; DSTI/EAS Division.

Table 8. Largest gain in technology intensity from acquired technology

	Country / Sectors	Intensity Total	Domestic	Imported	Origin	Share
	Australia 1986	Total	Domestic	Imported	Origin	Share
1.	Transport equipment	1.17	0.30	0.87	JPN	36.7
2.	Fabricated metal and machinery	0.80	0.35	0.45	USA	31.2
3.	Construction	0.73	0.50	0.23	USA	30.1
4.	Chemicals, oil & coal	0.68	0.25	0.43	USA	24.3
5.	Social & personal services	0.66	0.28	0.38	USA	39.8
	Total	0.48	0.25	0.23	USA	34.8
	Canada 1990	Total	Domestic	Imported	Origin	Share
1.	Computers & office machinery	6.82	0.35	6.47	USA	77.0
2.	Communication &	3.87	0.08	3.79	USA	73.1
3.	Shipbuilding	3.33	1.95	1.38	USA	73.0
4.	Aerospace	2.80	0.09	2.71	USA	78.1
5.	Communication	2.08	1.48	0.60	USA	74.0
	Total	0.49	0.17	0.33	USA	75.2
	Denmark 1990	Total	Domestic	Imported	Origin	Share
1.	Electrical machinery	1.38	0.32	1.06	ROO	24.1
2.	Transport machinery &	1.06	0.36	0.71	GER	24.4
3.	Chemicals	1.00	0.16	0.84	ROO	30.3
4.	Non-electrical equipment	0.79	0.20	0.60	GER	26.1
5.	Agriculture, forestry & fishing	0.65	0.35	0.30	ROO	28.2
	Total	0.41	0.17	0.24	ROO	27.8
	France 1990	Total	Domestic	Imported	Origin	Share
1.	Aerospace	4.42	1.74	2.68	USA	51.2
2.	Computers & office machinery	3.89	1.04	2.85	USA	45.1
3.	Shipbuilding	1.45	0.57	0.88	USA	18.5
4.	Communication	1.35	1.08	0.27	USA	27.8
5.	Other Transport	1.27	1.08	0.19	GER	28.7
	Total	0.61	0.35	0.26	USA	31.9
	Germany 1990	Total	Domestic	Imported	Origin	Share
1.	Aerospace	2.54	0.66	1.88	FRA	46.1
2.	Shipbuilding	1.83	1.47	0.36	ROO	26.0
3.	Computers & office machinery	1.77	0.65	1.12	USA	25.8
4.	Rubber & plastic products	1.72	1.24	0.49	ROO	28.2
5.	Communication	1.50	1.22	0.28	ROO	23.4
	Total	0.75	0.55	0.20	ROO	22.9

	Country / Sectors	Intensity Total	Domestic	Imported	Origin	Share
	Italy 1985	Total	Domestic	Imported	Origin	Share
1.	Aerospace	3.25	0.21	3.04	USA	53.1
2.	Computers & office machinery	2.62	0.28	2.35	USA	31.9
3.	Communication &	1.66	0.26	1.40	GER	23.7
4.	Communication	1.53	0.85	0.68	GER	21.8
5.	Pharmaceuticals	1.09	0.35	0.74	ROO	28.6
	Total	0.36	0.19	0.17	GER	22.9
	Japan 1990	Total	Domestic	Imported	Origin	Share
1.	Aerospace	5.16	0.64	4.51	USA	93.4
2.	Computers & office machinery	2.91	2.37	0.54	USA	73.2
3.	Other Transport	2.10	2.06	0.04	DAE	33.6
4.	Shipbuilding	1.91	1.84	0.07	USA	55.1
5.	Rubber & plastic products	1.90	1.84	0.06	USA	34.3
	Total	0.94	0.87	0.07	USA	57.8
	Netherlands 1986	Total	Domestic	Imported	Origin	Share
1.	Aerospace	8.12	0.44	7.68	USA	45.9
2.	Computers & office machinery	2.34	0.95	1.39	USA	27.3
3.	Electrical machinery	2.26	0.08	2.17	GER	28.0
4.	Motor vehicles	2.16	0.83	1.34	ROO	31.4
5.	Pharmaceuticals	2.12	0.24	1.89	ROO	34.1
	Total	0.58	0.18	0.40	GER	26.3
	UK 1990	Total	Domestic	Imported	Origin	Share
1.	Aerospace	4.17	0.37	3.81	ROW	62.9
2.	Computers & office machinery	3.37	0.80	2.56	USA	34.0
3.	Communication &	1.78	0.26	1.52	USA	25.2
4.	Communication	1.69	1.02	0.66	USA	20.6
5.	Instruments	1.37	0.62	0.75	USA	21.9
	Total	0.60	0.27	0.33	USA	20.0
	US 1990	Total	Domestic	Imported	Origin	Share
1.	Computers & office machinery	3.02	1.91	1.11	DAE	45.3
2.	Communication	1.60	1.48	0.13	DAE	38.6
3.	Instruments	1.60	1.33	0.28	DAE	34.2
4.	Electrical machinery	1.57	1.34	0.23	DAE	31.5
5.	Aerospace	1.49	1.06	0.43	FRA	22.9
	Total	0.68	0.59	0.09	JPN	29.8

Source: OECD input-output database; DSTI/EAS Division.

Table 9. Share of Imports by Country of Origin

Comparison of Dollar Flows and Weighted Technology Content

Destination country	Origin country	Share based on technology content	Share based on currency value	Ratio of technology currency value
Australia	USA	34.8	20.9	1.7
(1986)	JPN	23.6	23.7	1.0
	GER	8.3	8.5	1.0
Canada	USA	75.2	67.1	1.1
(1990)	JPN	7.3	7.8	0.9
	DAE	5.4	6.5	0.8
Denmark	ROO	27.8	29.3	0.9
(1990)	GER	22.9	24.0	1.0
	USA	12.6	5.9	2.1
France	USA	31.9	8.6	3.7
(1990)	GER	20.1	21.1	1.0
	ROO	14.6	24.5	0.6
Germany	ROO	22.9	28.0	0.8
(1990)	USA	18.3	7.0	2.6
	FRA	17.2	12.7	1.4
Italy	GER	22.9	23.3	1.0
(1985)	USA	20.5	6.7	3.0
	ROO	15.6	19.2	0.8
Japan	USA	57.8	27.7	2.1
(1990)	DAE	14.7	24.3	0.6
	GER	7.6	7.5	1.0
Netherlands	GER	26.3	30.1	0.9
(1986)	ROO	22.5	26.8	0.8
	USA	20.0	7.8	2.6
United Kingdom	USA	20.0	9.5	2.1
(1990)	ROW	19.0	13.2	1.4
	GER	14.8	17.3	0.9
United States	JPN	29.8	21.2	1.4
(1990)	DAE	23.9	20.1	1.2
	ROW	11.6	16.2	0.7

Source: OECD input-output database; DSTI/EAS Division.

Table A.1. Available Years of Input-Output Tables for 10 OECD Countries

	1960s	*1970s*	*1980s*	*1990s*
Australia	1968	1974	1986	
Canada		1971, 1976	1981, 1986	1990
Denmark	Annually from 1966 to 1990			
France		1972, 1977	1980, 1985	1990
Germany		1978	1986	1990
Italy			1985	
Japan		1970, 1975	1980, 1985	1990
Netherlands		1972, 1977	1981, 1986	
UK	1968	1979	1984	1990
US		1972, 1977	1982, 1985	1990

Table A-2 Sectoral Availability in Intermediate and Investment Flows Matrix

ISIC Sectors	Australia*		Canada		Denmark		France		Germany		Italy		Japan**		Netherlands		United Kingdom		United States	
	INT	INV	INT	INV	INT	INV	INT	INV	INT	INV	INT	INV	INT	INV	INT	INV	INT	INV	INT	INV
1 Agriculture, forestry and fishing																				
2 Mining & quarrying																				
3 Food drinks & tobacco																				
4 Textiles, footwear & leather																				
5 Wood, cork & furniture		x						x												
6 Paper, print & publishing																				
7 Chemicals		+8, 9				+ 8, 9, 10			+8	+8				+8						+8
8 Pharmaceuticals		x				x			x	x				x						x
9 Petroleum refining		x				x								x						
10 Rubber & plastic products		x				x								x						
11 Stone, clay & glass		x																		
12 Ferrous metal		+13				+13									+13	+13				
13 Non-ferrous metals		x				x									x	x				
14 Fabricated metal		+15to18,23																		
15 Other non-electrical machinery		x			+16	+16		+ 23												
16 Computers & office machinery	x	x			x	x		+ 17, 18						x						
17 Electrical machinery		x				+18		x	+18	+18				+16, 18	+18	+18				
18 Communication & semiconductors	+16	x				x		x	x	x				x	x	x				
19 Shipbuilding		+20,21,22				x		+ 22	+20	+20				+ 20,21,22						
20 Other Transport		x			+ 21, 22	+19, 21to23		+ 21	x	x				x						
21 Motor vehicles		x			x	x		x						x						
22 Aerospace		x			x	x		x						x						
23 Instruments		x				x		x												
24 Other manufacturing		+5,10,11						+5						+ 9, 10						
25 Electricity, gas & water																				
26 Construction																				
27 Wholesale & retail trade						+28														+28
28 Hotels & restaurants	x	x				x								x						x
29 Transport & storage		+30																		
30 Communication		x																		
31 Finance & insurance		+32					+32	+32												
32 Real estate & business services		x					x	x												
33 Social & personal services	+ 28, 34	+28												+28						

INT= Intermediate flow matrix, INV= Investment flow matrix, x = unavailable sector (set to zero)

*) Investment data only available for 1986/87.

**) Complete 36 sectors are available for 1985 and 1990 investment data.

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