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Estimation of inter-industry domestic and international R&D stocks for Belgium

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Abstract – This Working Paper deals with the estimation of direct, inter-industry domestic and international R&D stocks for 25 Belgian industries over the period 1995-2007. Two categories of stocks are constructed to estimate potential rent spillovers and knowledge spillovers. Domestic inter-industry and foreign R&D stocks are weighted with Supply and Use tables and bilateral trade data to estimate rent spillovers (through intermediate consumption) and with international patent citations matrices to estimate knowledge spillovers.

Abstract – Ce Working Paper traite de l'estimation de stocks de R&D directs, domestiques interindustriels et internationaux pour 25 branches d'activité belges sur la période 1995-2007. Deux catégories de stocks sont construites pour estimer les « rent spillovers » et les « knowledge spillovers » potentiels. Les stocks de R&D domestiques interindustriels et étrangers sont pondérés à l'aide des tableaux emplois-ressources et des données sur le commerce international pour estimer les « rent spillovers » et à l'aide de matrices de citations de brevets pour les « knowledge spillovers ».

Abstract – Deze Working Paper behandelt de raming van de directe, de binnenlandse intersectorale en de internationale O&O-voorraden voor 25 Belgische bedrijfstakken over de periode 1995-2007. Er worden twee categorieën voorraden opgesteld om potentiële rent spillovers en kennisspillovers te ramen. De binnenlandse intersectorale en de buitenlandse O&O-voorraden worden gewogen op basis van de aanbod- en gebruikstabellen en gegevens inzake internationale handel om de rent spillovers te ramen (via intermediaire consumptie) en op basis van matrices van internationale octrooicitaties voor de kennisspillovers.

Jel Classification - C81, 030.

Keywords – Domestic R&D stocks, international R&D stocks, spillovers.

Executive summary

Research and Development (R&D) activities are generally considered as one of the main determinants of productivity growth. Not only own R&D activities may affect innovation and productivity growth of firms but also R&D performed by other domestic or foreign firms (R&D spillovers). Two categories of spillovers are usually distinguished in the literature: rent spillovers, occurring when R&D intensive inputs are purchased at less than their full "quality" price, and knowledge spillovers, corresponding to the transfer of knowledge and ideas between firms.

To test for the presence of R&D spillovers in Belgium[1], the construction of R&D stocks are necessary. This Working Paper describes the methods usually applied to construct R&D stocks and estimates direct, inter-industry domestic and foreign R&D stocks for 25 Belgian industries over the period 1995-2007.

Direct stocks are computed according to the perpetual inventory method on the basis of R&D expenditures in constant prices. Two categories of stocks are constructed to estimate potential rent spillovers and knowledge spillovers. Domestic inter-industry and foreign R&D stocks are weighted with Supply and Use tables (SUT) and bilateral trade data to estimate rent spillovers (through intermediate consumption) and with international patent citations matrices to estimate knowledge spillovers. A patent citation can be related to a knowledge flow from the cited country/industry to the citing country/industry.

Data show that, in Belgium, R&D activity is highly concentrated in two knowledge intensive manufacturing industries: Chemicals and chemical products and Electrical and optical equipment. At the end of the period, Coke and, to a lesser extent, Rubber and plastics and Manufacturing n.e.c and recycling are industries benefiting the most from R&D of the other Belgian industries via their intermediate consumption. Over the whole period, foreign R&D stocks are particularly high in Transport equipment, which uses a lot of imported intermediate inputs containing a lot of R&D activities. To a lesser extent, Coke, Chemicals and Electrical and optical equipment also benefit from an important foreign R&D stock. These sectors are characterised by an important presence in Belgium of enterprises under foreign control.

Over the period 1995-2007, indirect domestic stocks and foreign stocks constructed with patent citations matrices are particularly high in Machinery, not elsewhere classified and Electrical and optical equipment. Chemicals and chemical products also benefit from very high foreign stocks and high indirect domestic stocks. To a lesser extent, Wood, Rubber and plastics products and Manufacturing n.e.c.; recycling have also relatively high levels of both stocks in comparison with the other sectors.

For each industry, the inter-industry domestic R&D stock and the foreign R&D stock depend in fact on a few industries/countries that are important in terms of intermediate consumption or patent citations for the concerned industry and/or that are intensive in R&D activities. Two major sectors contribute to the inter-industry domestic stock (via SUT) of a lot of industries: Chemicals and Renting of material &

[1] That was the objective of the Working Paper: B. Biatour, Dumont, M., Kegels, C. (2011), "The determinants of industry-level total factor productivity in Belgium", Federal Planning Bureau, WP 7-11.

equipment and other business. Chemicals and Chemical products and Electrical and optical equipment appear often as source of international spillovers (via SUT and patent citations matrices) and source of knowledge spillovers among Belgian industries. These two sectors are dominated by multinational enterprises, which can facilitate spillovers between countries. A lot of Belgian industries also benefit from R&D activities of the same sector abroad. The same countries are always identified as source of international spillovers: the neighbouring countries (Germany, France, The Netherlands and the United Kingdom), the United States and Japan.

Synthèse

Les activités de recherche et développement (R&D) sont généralement considérées comme un des principaux déterminants de la croissance de la productivité. Les activités de R&D réalisées dans une entreprise ont non seulement un impact sur l'innovation et la productivité de l'entreprise en question, mais peuvent aussi contribuer à la productivité d'autres entreprises dans le pays ou à l'étranger (spillovers). Deux catégories d'externalités positives ou « spillovers » sont habituellement distinguées dans la littérature : « les rent spillovers » survenant lors de l'achat d'inputs intensifs en R&D dont le prix ne reflète pas totalement la qualité des inputs et les « knowledge spilllovers » correspondant à des transferts d'idées et de connaissances entre les entreprises.

Pour tester la présence de spillovers de R&D en Belgique[2], il est nécessaire de disposer de stocks de R&D. Ce Working Paper décrit les méthodes habituellement utilisées pour construire les stocks de R&D et estime des stocks de R&D directs, domestiques interindustriels et étrangers pour 25 branches d'activité belges sur la période 1995-2007.

Les stocks directs sont estimés selon la méthode de l'inventaire permanent à partir de dépenses de R&D à prix constants. Deux catégories de stocks sont construites pour estimer les « rent spillovers » et les « knowledge spillovers » potentiels. Les stocks de R&D domestiques interindustriels et étrangers sont pondérés à l'aide des tableaux emplois-ressources (SUT) et des données sur le commerce international pour estimer les « rent spillovers » et à l'aide de matrices de citations de brevets pour les « knowledge spillovers ». Une citation de brevet peut être considérée comme un flux de connaissances provenant de l'industrie/pays cité vers l'industrie/pays citant.

Les données indiquent qu'en Belgique, les activités de R&D sont fortement concentrées dans deux industries manufacturières intensives en connaissances : l'Industrie chimique et la Fabrication d'équipements électriques et électroniques. A la fin de la période, la Cokéfaction, raffinage et industries nucléaires et, dans une moindre mesure, l'Industrie du caoutchouc et des plastiques et les Autres industries manufacturières représentent les branches d'activité bénéficiant le plus de la R&D des autres secteurs belges via leurs consommations intermédiaires. Sur toute la période, les stocks de R&D étrangers sont particulièrement élevés dans la Fabrication de matériel de transport qui utilise beaucoup d'inputs intermédiaires importés intensifs en R&D. Dans une moindre mesure, la Cokéfaction, l'Industrie chimique et la Fabrication d'équipements électriques et électroniques bénéficient aussi d'importants stocks de R&D étrangers. Ces secteurs sont caractérisés par une forte présence en Belgique d'entreprises sous contrôle étranger.

Sur la période 1995-2007, les stocks de R&D domestiques indirects et étrangers basés sur les matrices de citations de brevets sont particulièrement élevés dans la Fabrication de machines et équipements et dans la Fabrication d'équipements électriques et électroniques. L'Industrie chimique bénéficie, elle aussi, de stocks de R&D domestiques indirects et étrangers très élevés. Dans une moindre mesure, l'Industrie du bois, l'Industrie du caoutchouc et plastiques et les Autres industries manufacturières ont aussi des niveaux relativement élevés des deux stocks de R&D en comparaison avec les autres secteurs.

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[2] C'était l'objectif du Working Paper : B. Biatour, Dumont, M., Kegels, C. (2011), "The determinants of industry-level total factor productivity in Belgium", Federal Planning Bureau, WP 7-11.

Pour chaque industrie, le stock domestique indirect et le stock étranger dépendent en fait de quelques industries/pays qui sont importants en termes de consommations intermédiaires ou de citations de brevets pour l'industrie concernée et/ou qui sont intensifs en activités de R&D. Deux principaux secteurs contribuent au stock domestique indirect (via les SUT) de beaucoup de branches d'activité : l'Industrie chimique et la Location et services aux entreprises. L'Industrie chimique et la Fabrication d'équipements électriques et électroniques apparaissent souvent comme source de spillovers internationaux (via les SUT et les matrices de citations de brevets) et comme source de knowledge spillovers au sein des industries belges. Il s'agit de deux branches d'activité dominées par des entreprises multinationales, ce qui peut faciliter les spillovers entre pays. Beaucoup d'industries belges bénéficient aussi des activités de R&D de la même branche d'activité à l'étranger. Les mêmes pays sont toujours identifiés comme source de spillovers internationaux : les pays voisins (l'Allemagne, la France, les Pays-Bas et le Royaume-Uni), les Etats-Unis et le Japon.

Synthese

De activiteiten van onderzoek en ontwikkeling (O&O) worden doorgaans beschouwd als een van de voornaamste determinanten van de productiviteitsgroei. De O&O-activiteiten die in een onderneming gerealiseerd worden, hebben niet alleen een impact op de innovatie en de productiviteit van de onderneming, maar kunnen ook bijdragen tot de productiviteit van andere ondernemingen in binnen- of buitenland (O&O-spillovers). In de literatuur worden doorgaans twee categorieën positieve externaliteiten of "spillovers" onderscheiden: de rent spillovers, die voorkomen bij de aankoop van O&O-intensieve input waarvan de prijs de kwaliteit van de input niet helemaal weerspiegelt, en de kennisspillovers, die verband houden met de overdracht van ideeën en kennis tussen ondernemingen.

Om de aanwezigheid van spillovers in België na te gaan[3], zijn O&O-voorraden vereist. Deze Working Paper beschrijft de methoden die doorgaans gebruikt worden om de O&O-voorraden op te bouwen en maakt een raming van de directe, de binnenlandse intersectorale en de buitenlandse O&O-voorraden voor 25 Belgische bedrijfstakken over de periode 1995-2007.

De directe voorraden worden geraamd volgens de methode van permanente inventarisatie op basis van O&O-uitgaven tegen constante prijzen. Om een raming te maken van de rent spillovers en de kennisspillovers worden twee categorieën voorraden opgesteld. De binnenlandse intersectorale en de buitenlandse O&O-voorraden worden gewogen op basis van de aanbod- en gebruikstabellen (AGT) en gegevens inzake internationale handel om de rent spillovers te ramen (via intermediaire consumptie) en op basis van matrices van internationale octrooicitaties voor de kennisspillovers. Een octrooicitatie kan beschouwd worden als een kennisstroom van de (het) geciteerde bedrijfstak (land) naar de (het) citerende bedrijfstak (land).

De gegevens tonen aan dat de O&O-activiteiten in België sterk geconcentreerd zijn in twee kennisintensieve verwerkende bedrijfstakken: de Chemische nijverheid en de Vervaardiging van elektrische en elektronische apparaten. Aan het einde van de periode zijn de Vervaardiging van cokes, geraffineerde aardolieproducten en splijt- en kweekstoffen en, in mindere mate, de Vervaardiging van rubber en kunststoffen en de Overige verwerkende nijverheid de bedrijfstakken die het meest profiteren van O&O van andere Belgische sectoren via hun intermediair verbruik. Over de volledige periode zijn de buitenlandse O&O-voorraden bijzonder groot in de Vervaardiging van transportmiddelen, die veel gebruik maakt van O&O-intensieve geïmporteerde intermediaire input. De vervaardiging van Cokes, de Chemische industrie en de Vervaardiging van elektrische en elektronische apparaten profiteren ook, zij het in mindere mate, van aanzienlijke buitenlandse O&O-voorraden. Die sectoren worden gekenmerkt door een sterke aanwezigheid in België van ondernemingen onder buitenlandse controle.

Over de periode 1995-2007 zijn de binnenlandse indirecte en de buitenlandse O&O-voorraden op basis van matrices van octrooicitaties bijzonder groot in de Vervaardiging van machines en apparaten en in de Vervaardiging van elektrische en elektronische apparaten. De Chemische industrie profiteert zelf ook van de uiterst hoge binnenlandse indirecte en de buitenlandse O&O-voorraden. In mindere mate hebben ook de Houtindustrie, de Vervaardiging van producten van rubber en kunststof en de Overige

[3] Dat is de doelstelling van de Working Paper: B. Biatour, Dumont, M., Kegels, C. (2011), "The determinants of industry-level total factor productivity in Belgium", Federal Planning Bureau, WP 7-11.

verwerkende industrieën relatief hoge niveaus voor beide O&O-voorraden in vergelijking met de andere sectoren.

Voor elke bedrijfstak zijn de binnenlandse indirecte en de buitenlandse voorraden in feite afhankelijk van enkele industrieën/landen die belangrijk zijn in termen van intermediair verbruik of octrooicitaties voor de desbetreffende bedrijfstak en/of intensief zijn in O&O-activiteiten. Twee belangrijke sectoren dragen bij tot de binnenlandse indirecte voorraad (via de AGT) van vele bedrijfstakken: de Chemische industrie en Verhuur en zakelijke dienstverlening. De Chemische industrie en de Vervaardiging van elektrische en elektronische apparaten blijken vaak een bron van internationale spillovers (via de AGT en de matrices van octrooicitaties) en een bron van knowledge spillovers binnen de Belgische bedrijfstakken. Beide bedrijfstakken worden gedomineerd door multinationals, wat de spillovers tussen landen kan bevorderen. Ook veel Belgische bedrijfstakken profiteren van de O&O-activiteiten door hun overeenkomstige bedrijfstakken in het buitenland. Dezelfde landen worden altijd geïdentificeerd als bron van internationale spillovers: de buurlanden (Duitsland, Frankrijk, Nederland en het Verenigd Koninkrijk), de Verenigde Staten en Japan.

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1. Introduction

The determinants of productivity growth are a subject of considerable interest to economists and policy makers. It is particularly true in Belgium where changes in the evolution of productivity growth took place from the mid-1990s. Belgium was more productive in terms of real GDP per hour worked than France, Germany, The Netherlands and the US until 2007, but from the mid-1990s, the productivity growth rate in Belgium started to slow down and became negative after 2007[1]. In 2009, the productivity gap between Belgium and France, Germany, The Netherlands and the US was largely reduced, or even closed.

Previous studies showed that the slowdown in productivity growth was mainly due to the total factor productivity growth (TFP). TFP growth measures the evolution of the overall efficiency with which labour and capital are combined in the production process. It is usually considered as a proxy for disembodied technological change. In Belgium, the main contribution to productivity growth is capital deepening, measuring the increase in the capital intensity of productive process.

To understand the slowdown in TFP in Belgium, the objective of the previous Working Paper 7-11[2] was the econometric estimation for Belgium at an industry-level of the impact on total factor productivity of the main determinants forward in the literature. Econometric results show that R&D is an important determinant. Not only own R&D activities affect innovation and productivity growth, but firms also benefit from R&D performed by other domestic or foreign firms (R&D spillovers). Results show that the impact is more pronounced for manufacturing than for other industries (services, construction and utilities). For manufacturing industries, there is robust evidence of a positive impact of intra-industry (own) R&D activities as well as positive domestic inter-industry R&D spillovers and foreign (knowledge) spillovers whereas in services only domestic (patent-weighted) R&D stocks are found to have had a statistically significant positive impact on TFP. However, even the group of manufacturing industries appears to be heterogeneous. The impact of intra-industry R&D investment is only significantly positive for high-tech industries, the positive domestic inter-industry spillovers only for medium-tech and high-tech industries and the foreign knowledge spillovers only for medium-tech industries. For this econometric analysis, direct, inter-industry domestic and foreign stocks were constructed for Belgium at an industry-level. This Working Paper explains the method of construction of these stocks.

The paper is organised as follows. Section 2 briefly reviews the theoretical framework of R&D spillovers. Section 3 presents the methods used in the empirical literature to construct direct, inter-industry domestic and foreign stocks. Section 4 provides an application to Belgian data for the period 1995-2007. Finally, Section 5 concludes.

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1 Real GDP per hour worked (constant 2009 prices, purchasing power parities), Eurostat data, data from Graph 1, FPB WP 7-11.

2 B. Biatour, Dumont, M., Kegels, C. (2011), "The determinants of industry-level total factor productivity in Belgium", Federal Planning Bureau, WP 7-11.

2. Theoretical framework

R&D activities realised in a firm or in an industry produce innovations of product, process or organisation, leading to an increase in productivity of the firm or industry by improving the qualitiy or by reducing the production costs of existing goods or by widening the range of final goods or intermediate inputs (Hall et al (2009)). Due to the quasi-public good characteristic of technological knowledge, R&D activities realised in a firm/industry may also have a positive external effect on the production possibilities of other firms (Romer (1986)). Knowledge is considered to be a quasi-public good because it has the two following properties: non-rivalry (the consumption by an individual does not limit the consumption by others) and (at least partial) non-excludability (no one can be excluded from consumption of the good). The non-excludability is, however, partial because some forms of knowledge may be appropriated through patents or trade secrets (Stiglitz (1999)).

The benefits of R&D activities performed in one firm/industry may spill over into the other firms that do not undertake R&D activities. Griliches (1979) distinguished two categories of spillovers: rent spillovers and knowledge spillovers. The first category occurs when R&D intensive inputs are purchased from other industries at less than their full "quality" price, preventing the complete appropriation of the innovation rent by the innovator, e.g. due to strong competition or measurement problems. Another source of rent spillovers comes from measurement problems: prices are not completely corrected for quality improvements (for example without hedonic prices) (Griliches (1971 cited in Griliches (1979), Hall et al. (2009)). These kinds of spillovers are always embodied in economic transactions.

The second category of spillovers – knowledge spillovers – represents true spillovers and is defined by Griliches (1979) as ideas borrowed by the research teams of industry i from the research results of industry j that provide a benefit to industry i's innovation capacity. Poor patent protection, the inability to keep innovations secret, reverse engineering, imitation, meetings, conferences and mobility of (R&D) staff are possible channels of knowledge spillovers. Those spillovers are not necessarily related to economic transactions since it is possible that two industries which do not buy much from each other but are working on similar things, benefit from each other's research. They can be facilitated by technological linkages between sectors.

Rent spillovers as well as knowledge spillovers are not limited to national borders. Due to the globalisation of the economy, the international diffusion and the absorption of knowledge have become recurring and increasing characteristics of the world economy. An economy/industry/firm may have beneficial effects on its productivity from R&D activities performed in other countries. These effects are expected to be stronger the more open the economy is to foreign trade (Coe and Helpman, (1995)).

3. The empirical literature

3.1. Inter-industry domestic spillovers

Van Pottelsberghe (1997) summarizes the various channels through which an industry may benefit from R&D spillovers from other industries (inter-industry spillovers). He distinguishes three types of rent spillovers going through economic transactions: the input-related rent spillovers, the investment-related rent spillovers and the patent-related rent spillovers. In each case, rent spillovers may or may not take place, depending on the price of the transaction. Mohnen (2001) cites also the hiring of workers, research collaborations and mergers and acquisitions as possible channels of rent spillovers. Knowledge spillovers can follow various channels such as flows of patents, attendance at workshops, seminars, mobility of R&D personnel, imitation, impossibility to keep innovation secret... They are not necessarily associated with an economic transaction and can be facilitated by technological linkages between sectors.

The two first categories of rent spillovers – the input – and investment-related rent spillovers- can arise in the case of the purchase of intermediate inputs or investment goods at a price that does not totally reflect the quality improvement resulting from R&D investments.

The R&D spillover variable is usually measured as a weighted sum of R&D stocks from sources outside the firm/industry:

$$S_{i,t} = \sum_{j=1,\, j\neq i}^{N} a_{ji,t} \cdot R_{j,t} \qquad (1)$$

where the weights $a_{ji,t}$ are proportional to flows including intermediate input transactions, investments in capital goods (Sveikauskas, (1981)) between firm or industry i, the receiver of R&D spillover and firm or industry j, the source of R&D spillovers. $R_{j,t}$ is the R&D stock of firm/industry *j*. Terleckyj (1974) was one of the first researchers to estimate spillovers using this method which is largely developed in the literature.

The third category of rent spillovers cited by Van Potteslberghe (1997), the patent-related rent spillovers is associated with the use by industry or firm i of patents granted to industry j. Technology flows matrix (Scherer (1982) matrix for the United States, Yale matrix for Canada) are used to estimate weights $a_{ji,t}$ in equation (1). They contain patent data classified by the potential user and producer industries. The Yale matrix (described in Putnam and Evenson (1994)) is constructed on the basis of data from the Canadian Patent Office. Between 1972 and 1995, the Canadian Office assigned, in addition to an IPC code (International Patent Classification), an industry of manufacture (IOM) and a sector of use (SOU) code to each of over 300.000 granted patents. The Yale Technology Concordance (YTC) utilised tabulated information on these patents to determine the probability that a patent with a specific IPC code has a particular IOM-SOU combination. Since other nations only report IPC information, those probabilities allow researchers to infer the IOM-SOU details of a patent based purely on the legal technological

details offered by the IPC grouping. Johnson (2002) created a translation to the international ISIC classification.

Pure knowledge spillovers, independant of any economic transactions, are difficult to measure. The first attempt to capture these spillovers was made by Jaffe (1986), who developed the technological proximity concept. Jaffe constructed a measure of technological distance between firms on the basis of the distribution of firm's patenting activities over technology fields (cited in Verspagen 1997). He examined whether the R&D of neighbouring firms in technology space has an observable impact on the firm's R&D success. Verspagen (2007) developed 3 types of matrices from patent data granted by the US Patent Office and by the European Patent Office for the 1980s to estimate knowledge spillovers.

Empirically, the distinction between rent spillovers and knowledge spillovers is very difficult because they are likely to occur simultaneously. In economic transactions, knowledge spillovers may be associated with rent spillovers. Indeed, if an industry purchases intermediate inputs from another industry, they are more likely to be technologically similar and to benefit from each other's innovations (Van Pottelsberghe, (1997)). Some researchers use technology flows matrices such as the Yale matrix to measure knowledge spillovers (Van Meijl (1995)). Verspagen (2007) argues that these matrices measure knowledge spillovers related to economic transaction, rather than pure knowledge spillovers related to technological linkages between industries. They measure in fact mainly rent spillovers.

In the literature on spillovers, two different approaches are developed to model R&D. In the first approach, R&D expenditures are accumulated to constitute a knowledge stock. Following the perpetual inventory method (e.g. Coe and Helpman (1995), Los and Verspagen (2000)), the R&D stock of industry *i* at time *t* is equal to the new R&D expenditure at time *t* ($RD_{i,t}$) plus the R&D stock at time t-1 minus depreciation:

$$R_{i,t} = RD_{i,t} + (1-\delta) \cdot R_{i,t-1} \qquad (2)$$

In theory, the depreciation rate should vary by industry and according to the nature of the R&D activities. Fundamental R&D or applied R&D should have different rates of depreciation. However, Griliches and Mairesse (1984), Mairesse and Cunéo (1985), Bernstein (1988), Bernstein and Nadiri (1989), Hall and Mairesse (1995), and Harhoff (1994), report small differences, if any, in the estimation of R&D elasticity when the rate of depreciation varies from about 8% to 25% (cited in Hall, Mairesse and Mohnen (2009)). Guellec and van Pottelsberghe (2001) also mention that according to sensibility analysis, the results of the regressions do not change significantly with the chosen depreciation rate. That is why many empirical studies assume an arbitrary depreciation rate of 10% to 15% per annum. Nadiri and Prucha (1996) apply a model of factor demand to estimate R&D's depreciation rate for the US total manufacturing sector. They find a 12% depreciation rate.

Hall, Mairesse and Mohnen (2009) show why the elasticity is not sensitive to the choice of depreciation rate. They assume that R&D grows over a long period at a constant (firm-specific) rate g_i and according to a constant depreciation rate δ_i (firm-specific):

$$R_{i,t} \cong \frac{RD_{i,t}}{\delta_i + g_i} \quad or \quad \log R_{i,t} \cong \log RD_{i,t} - \log(\delta_i + g_i) \tag{3}$$

As long as the depreciation rate and the growth rate do not change much within a firm over time, the estimation of the elasticity of output with respect to R&D stock or expenditures will remain close. In equation (3), the depreciation and growth rate will be included in the firm effect. However, the authors show that the rate of return derived from the elasticity depends on the choice of the depreciation rate.

The utilisation of R&D stocks in a model in logarithms allows for the direct estimation of the output elasticity with respect to different R&D stocks. This elasticity is assumed to be constant. From this elasticity, a rate of return can be derived, which is not constant (see equations (10) and (11) below). The calculation of knowledge stocks requires long series of R&D expenditures to make an initial stock. If the data are not available, an initial stock can be estimated following the procedure suggested by Griliches (1979) assuming a constant growth rate of R&D investment[3]:

$$R_0 = \frac{RD_1}{(g + \delta)} \tag{4}$$

Where g is the average annual growth rate of R&D expenditures over the period for which R&D data are available and RD_1 is R&D expenditures.

The second approach to model R&D activities is the use of flow measured by R&D intensity (R&D expenditures over output or value added). With this measure, the depreciation rate is supposed to be 0. In this model, estimated coefficients are constant rates of return. The elasticity derived from the rates of return varies across industries. The choice between the two methods is sometimes determined by the availability of the data. The use of stocks requires long series of R&D expenditure or assumptions over the initial stock. This is not the case for R&D intensity, which is more easily available.

Most of the literature that measures the returns to R&D starts with a production function (primal approach), which allows to understand the link between the two measures of R&D.

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[3] Following the perpetual inventory model $R_{i,t} = RD_{i,t} + (1-\delta) \cdot R_{i,t-1}$

$R_t = RD_t + (1-\delta) RD_{t-1} + (1-\delta)^2 RD_{t-2} + (1-\delta)^3 RD_{t-3} + \ldots$

$R_t = RD_t + (1-\delta) \lambda RD_t + (1-\delta)^2 \lambda^2 RD_t + (1-\delta)^3 \lambda^3 RD_t + \ldots$

$R_t = RD_t \frac{1+g}{g+\delta} = \frac{RD_{t+1}}{g+\delta}$

Assuming a standard Cobb Douglas production function that includes the knowledge capital stock as a distinct factor of production (Griliches, Lichtenberg, (1984)):

$$Q(t) = A \cdot R(t)^{\beta} \cdot \prod_{i=1}^{4} X_i(t)^{\alpha^i} \cdot \exp(\mu t) \quad (5)$$

where Q(t) is output, R(t) the knowledge R&D capital stock, $X_1(t)$ the labour input, $X_2(t)$ the capital input, $X_3(t)$ the energy, $X_4(t)$ the intermediate inputs and A a constant. The total factor productivity (TFP) is defined as followed:

$$TFP(t) = \frac{Q(t)}{\prod_{i=1}^{4} X_i(t)^{\alpha^i}} \quad (6)$$

Assuming constant returns to scale, $\sum \alpha_i = 1$ and combining (5) and (6) gives:

$$TFP(t) = A. \cdot R(t)^{\beta} \cdot \exp(\mu t) \quad (7)$$

or in logarithms,

$$\ln TFP(t) = \ln A + \beta \ln R(t) + \mu t \quad (8)$$

β corresponds to the elasticity of output with respect to knowledge capital stock.

When differentiating equation (8) with respect to time, we obtain (with $\left[d \ln TFP(t)\right]/dt = \dot{T}/T = \Delta \ln TFP(t)$),

$$\frac{\dot{T}}{T} = \beta \frac{\dot{R}}{R} + \mu \quad (9)$$

From equation (5), the elasticity β is equal to:

$$\beta = \frac{\partial \ln Q}{\partial \ln R} = \frac{\partial Q}{\partial R} \cdot \frac{R}{Q}. \quad (10)$$

Then, equation (9) is rewritten as:

$$\frac{\dot{T}}{T} = \frac{\partial Q}{\partial R} \cdot \frac{R}{Q} \cdot \frac{\dot{R}}{R} + \mu = \rho \frac{\dot{R}}{Q} + \mu \quad (11)$$

Where $\rho = \partial Q / \partial R$ is the rate of return to R&D.

With R being R&D expenditure, equation (11) can be rewritten:

$$\frac{\dot{T}}{T} = \rho \frac{(RD - \delta R)}{Q} + \mu \approx \rho \frac{RD}{Q} + \mu \qquad (12)$$

Equation (12) shows that if the depreciation rate δ is close to 0, the net R&D investment may be estimated by the gross R&D expenditure.

In practice, estimating the effect of R&D on total factor productivity growth can be made by using a regression of the level in logarithm of total factor productivity on the level of R&D stock in logarithm (equation (8)). Own R&D stocks, inter-industry domestic stocks and foreign stocks can be introduced in the equation to test for the presence of spillovers. The estimated coefficients are elasticities[4]. Rates of return can be derived from elasticities (equation (10)) by multiplying estimated elasticities by the ratio Q/R, that varies over time.

The second way consists in the regression of the change in total factor productivity on a measure of R&D intensity (equation (11)). Own, inter-industry and foreign intensities may be introduced in the equation to test for the presence of spillovers. The estimated coefficients are rates of return. In a lot of studies, the estimated rate of return is said « excess » rate of return because the data on labour and capital are not corrected for the employment and capital devoted to R&D activities (double counting) (Van Pottelsberghe, (1998)).

Next to the primal approach, which estimates a production function with quantities as inputs, another major approach – the dual approach – using a cost function is also applied. Hall et al. (2009) discuss the differences between the primal and dual approach in some detail.

Various surveys of the economic literature on the estimation of R&D elasticities/rates of return and R&D spillovers are proposed by Nadiri (1993), Van Pottelsberghe (1997), Cameron (1998), Sveikauskas (2007), Hall et al. (2009).

3.2. International spillovers

The empirical literature shows that spillovers are not limited to domestic borders and that knowledge developed in a country may have an impact on the productivity of other countries. International R&D spillovers are transmitted through more or less the same channels as inter-industry spillovers (Mohnen, 2001): (1) international trade in final goods, intermediate inputs, investment goods, (2) foreign direct investment (FDI), (3) migration of scientists, attendance at workshop, seminars,... (4) publications in technical journals and scientific papers, referencing other publications, invention revelation through patenting, patent citations, (5) inter-

[4] See FPB WP 7-11, "The determinants of industry-level total factor productivity in Belgium" for a detailed econometric specification of R&D spillovers in Belgium and for results for a panel of 21 Belgian industries over the period 1988-2007.

national research collaborations or international mergers and acquisitions, (6) foreign technology payments (royalties on copyrights and trademarks, licensing fees, the purchase of patents, the payments of consulting services and the financing of R&D conducted abroad).

Theoretically, the distinction between rent spillovers linked with economic transactions and pure knowledge spillovers may also be made in the framework of international spillovers. Cincera and Van Pottelsberghe (2001), Hall, Mairesse and Mohnen (2009), and Mohnen (2001) present a survey of the economic literature on international R&D spillovers.

In the empirical literature, the foreign R&D stock for country/firm i is usually measured as a weighted sum of the other countries'/firms' R&D stocks:

$$S_{i,t} = \sum_{j=1}^{N} a_{ji,t} \cdot R_{j,t} \qquad (13)$$

The weight $a_{ji,t}$ may be estimated with import matrices, international patent matrices, patent citations matrices, FDI, R&D cooperation agreements, migration of R&D personnel,.... In each case, several variations of weights are found in the literature. For example, in the estimation of international rent spillovers via import matrices, the weight might be equal to the share of intermediate inputs from sector/country j to i in total production of sector i (Jacobs, Nahuis and Tang (2002)) $a_{ji,t} = M_{ji}/Q_i$ or in total production of sector j : $a_{ji,t} = M_{ji}/Q_j$ (Van Pottelsberghe (1997)) or in total intermediate inputs from j : $a_{ji,t} = M_{ji}/\sum_i M_{ji}$ (Terleckyj (1974)) or in total intermediate inputs to i $a_{ji,t} = M_{ji}/\sum_j M_{ji}$ (Coe and Helpman (1995) with imports data). Each aggregation has advantages and drawbacks.

The first weight – in percentage of total production of i – is sensitive to changes in trade patterns. A sector will have a higher foreign stock if it imports more from large countries with high domestic R&D stocks rather than if it imports the same goods in the same quantity but from a smaller country with smaller R&D stock. However the imported goods in the first case are not necessary more intensive in R&D than in the second case. The second measure - in percentage of total production of j- resolves this problem since the quantity produced by the country providing the inputs is taken into account. A large country with a large R&D stock will also have a high level of production. This second measure has, however, a drawback. If the country providing the inputs opens up to other markets and strongly increases its exportations and production, the weight will fall without the R&D content of the imported goods decreasing. The third measure – in percentage of total intermediate inputs from j - presents the same problem as the previous one: an increase in exportations of industry j providing inputs will have an impact on the weight, even though the R&D content of the imported goods will not necessary have changed. As Coe and Helpman (1995) note, the last aggregation may not adequately capture the role of international trade. The sum of the weights is equal to 1 for each sector i and therefore does not reflect the level of imports.

In his survey of the literature, Mohnen (2001) concludes that several studies fail to find strong evidence of international spillovers[5]. He notes that when various R&D indicators are introduced simultaneously in a regression, it sometimes happens that some R&D coefficients are not significant or even negative. One reason is the high collinearity between own, domestic and foreign R&D combined with a low number of observations. The problem of multicollinearity arises because many of the various R&D series move simultaneously over the period. Consequently, it is difficult to dissociate their separate contributions (Griliches (1979)).

[5] Park (1995), Vuori (1997), Hanel (1994), Basant and Fikkert (1996) cited in Mohnen (2001).

4. Application to Belgian data

4.1. Sources and construction of the data

In this paper, R&D stocks are computed according to the perpetual inventory method on the basis of R&D expenditures in constant prices. Data for the domestic R&D stocks are provided by the Belgian Science Policy Office and for foreign R&D stocks by the OECD (ANBERD database). Business R&D expenditures are expressed in constant US dollars (2000 PPPs prices). A number of assumptions have been made to fill missing values, e.g. average annual growth rates and proportionality factors.

Belgian inter-industry R&D stocks used to estimate potential rent spillovers were computed using weights derived from Supply and Use tables (SUT) from 1995 to 2005. Foreign R&D stocks were weighted using bilateral trade data by industry, provided by the National Bank of Belgium for the period 1995-2007 and using SUT. Bilateral trade data are not available for services. Due to data availability, the number of trade partners considered for the construction of the Belgian foreign R&D stocks was restricted to 20 OECD countries, representing 85.7% of total Belgian imports in 2007[6]. To test for possible knowledge spillovers, Belgian and foreign R&D stocks were weighted on the basis of international patent citations matrices from 1990 to 2003, developed by UNU-MERIT in the framework of the Demeter project[7]. Canada, Norway and Turkey were not considered for the calculation of foreign R&D stocks due to missing data. Inventors of both cited and citing patents are known by country and thus reflect the international flow of technological knowledge. Patents are classified using technology classes and industries according to the Yale/ OECD Concordance Table and aggregated into Demeter sectors.

The OECD considers two types of criteria to classify R&D expenditure by industry: by main activity or by product field. Allocating all R&D expenditures according to the principal activity of a firm may lead to a biased estimate of R&D spending, e.g. for large firms with important R&D activities in secondary activities. However, the advantage of this classification is its compatibility with industry-level National Accounts data. Data by product field are calculated by disaggregating the R&D expenditures of diversified firms into different activities. Belgium collects data both ways[8], contrary to most other countries. For Belgium, the two data series are used to estimate R&D stocks; for the other countries, when the two criteria are provided, the choice is made according to data availability.

[6] The countries are: France, The Netherlands, Germany, Italy, United Kingdom, Ireland, Denmark, Greece, Portugal, Spain, Sweden, Finland, Austria, Poland, Czech Republic, Turkey, Norway, United States, Canada and Japan.

[7] European project which aimed to build a system of tools based on applied modelling that can be used for ex ante evaluation of research and innovation policies at sector and European level (http://demeter-project.eu).

[8] R&D expenditures by industry according to the main activity are available over the period 1999-2007. Retropolations were made, based on the growth in R&D expenditures by product available over 1977-2007.

Following the perpetual inventory method (e.g. Coe and Helpman (1995), Los and Verspagen (2000)) the R&D stock of industry *i* at time *t* is equal to the new R&D expenditure at time *t* ($RD_{i,t}$) plus the R&D stock at time t-1 minus depreciation (depreciation rate fixed at 15%):

$$R_{i,t} = RD_{i,t} + (1-\delta)\cdot R_{i,t-1} \qquad (14)$$

To test for potential rent spillovers, inter-industry domestic stocks $\left(R_{i,t}^{inter}\right)$ for industry *i* are constructed as a weighted sum of the other industries' R&D stocks:

$$R_{i,t}^{inter} = \sum_{j=1, j\neq i}^{N} \frac{I_{ji,t}}{VA_{i,t}} \cdot R_{j,t}$$

where $R_{j,t}$ is the R&D stock of product *j*, $I_{ji,t}$ the domestic intermediate inputs from *j* to *i* and $VA_{i,t}$ value added of industry *i*.

Supply and use tables are product-by-industry matrices, i.e. $I_{ji,t}$ denotes the intermediate inputs of product j purchased by industry i. Given that, for Belgium, R&D expenditures are available by main activity and by product, the construction of R&D stocks by product j rather than by industry j is preferred with intermediate inputs as weight.

The foreign R&D stock $\left(R_{i,t}^{for}\right)$ for each Belgian industry *i* is constructed in a similar way:

$$R_{i,t}^{for} = \sum_{j=1}^{N} \sum_{k=1}^{K} \frac{I_{ji,t} \cdot \frac{M_{j,t}^{K}}{M_{j,t}}}{VA_{i,t}} \cdot R_{j,t}^{K}$$

where $R_{j,t}^{K}$ is the R&D stock of industry/product *j* in country K, $I_{ji,t}$ imported intermediate inputs of product *j* by industry *i*, $\frac{M_{j,t}^{K}}{M_{j,t}}$ the share of country K in total Belgian imports of products j and $VA_{j,t}$ the value added of industry *i* in Belgium. Due to data availability, imports from different countries are assumed to have the same industry-specific distribution[9].

To test for potential knowledge spillovers, another type of domestic and foreign R&D stocks has been constructed using international patent citations matrices[10]. A patent citation can be related to a knowledge flow from the cited country/industry to the citing country/industry. Using this information provides a domestic stock $\left(R_{i,t}^{inter,know}\right)$ and a foreign R&D stock $\left(R_{i,t}^{for,know}\right)$ for Belgian industry *i*, constructed in a similar way:

$$R_{i,t}^{inter(for),know} = \sum_{j=1}^{N} a_{ji,t} \cdot R_{j,t}$$

9 For instance, Belgian imports of chemical goods from Germany are distributed over Belgian industries in the same way as Belgian imports of chemical goods from the US.

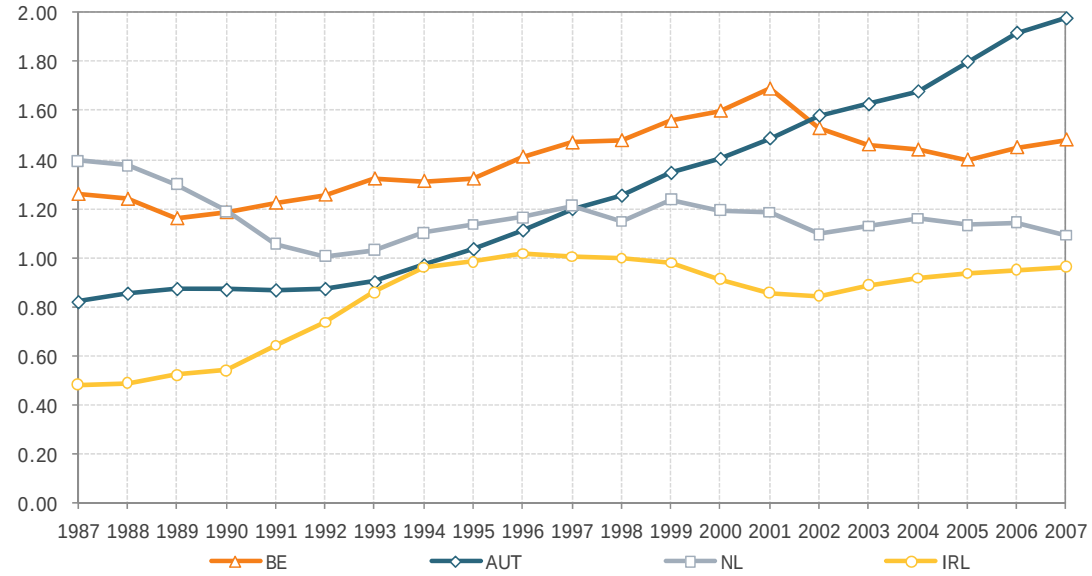
10 Kindly provided by Huub Meijers (UNU-MERIT).

where $R_{j,t}^{know}$ is the R&D stock of industry/country j, $a_{ji,t}$ is the number of patent citations from the cited country/sector j towards the citing Belgian sector i divided by the total citations towards the Belgian industries.

4.2. Description of the data

Graph 1 shows the R&D intensity of the business sector in Belgium and in 3 small neighbouring countries over the last twenty years available. The R&D intensity of the Belgian enterprises knew a strong growth from 1989 to 2001. A decrease is then observed until 2005 while the last two years are characterized by a recovery. Due to its strong increase, Belgium records the highest R&D intensity over the period 1991-2001. From 2001, intensity in Belgium decreased and went under Austria, which has known an impressive growth of its intensity since the beginning of the period.

Graph 1 **R&D intensity of enterprises sector**
in % of value added



Source: OECD data, EUKLEMS database.

Table 1 provides, for Belgium, the R&D intensity and R&D stocks by industry (classified according to main activity)[11] over the period 1995-2007. It appears that, in Belgium, R&D activity is highly concentrated in a small number of knowledge-intensive manufacturing industries: Chemicals and chemical products, Electrical and optical equipment and, at a considerable distance, Machinery not elsewhere classified, Transport equipment, Rubber and plastics products (in term of R&D intensity, not in term of stocks). R&D stocks are also relatively high in Basic metals and fabricated metal products in manufacturing industries and very high in Renting of material and equipment and other business activities in services sector, while R&D expenditures in percentage of value added are not particularly high in those two sectors. The

[11] For Belgium, R&D expenditures by industry according to the main activity are available over the period 1999-2007. Retropolations were made, based on the growth in R&D expenditures by product available over 1977-2007.

non-manufacturing sectors record particularly low R&D intensities.

Most industries witnessed an increase in R&D intensity and R&D stocks over the period. Chemicals and chemical products recorded the strongest growth of R&D intensity in terms of percentage points (+5.6 percentage points) thanks to the pharmaceutical industry which recorded a growth of 20.3 percentage points of its R&D intensity over the period 1995-2007. Inversely, R&D intensity of non pharmaceutical industry has decreased over the period. In 1995, R&D expenditure of pharmaceutical products accounted for 49.1% of total R&D expenditures of the chemical industry. They accounted for 77.9% in 2007. Other industries also knew a good growth of their R&D intensity: Transport equipment (+2.3 percentage points), Rubber and plastics products (+ 1.2%), Machinery, not elsewhere classified (+1.1) and Telecommunications (+1.6%).

Coke, refined petroleum products and nuclear fuel and Electrical and optical equipment recorded a strong decrease in R&D intensity over the considered period (-3.1 and -2.5 percentage points, respectively). They also recorded a strong decrease of their stocks over the period 1995-2007. It is also the case of the stock of Pulp, paper, paper products, printing and publishing, and Real estate activities. The other sectors knew an increase in their stocks over the 1995-2007 period.

Table 1 R&D intensity (in % of value added) and industry-level R&D stocks
millions constant (2000) PPP US dollars

	R&D Intensity				R&D stocks			
Industry	1995	2000	2005	2007	1995	2000	2005	2007
Agriculture, hunting, forestry and fishing	0.72	0.44	0.91	1.08	126.2	132.9	125.6	138.4
Mining and quarrying	0.57	0.54	0.93	0.61	9.3	13.0	16.8	15.7
Food products, beverages and tobacco	0.91	1.46	1.62	1.48	276.5	404.4	536.0	552.5
Textiles, textile products, leather and footwear	1.83	3.36	2.29	2.64	248.3	349.9	340.4	332.8
Wood and products of wood and cork	0.90	1.01	0.68	0.59	32.1	36.2	34.1	34.7
Pulp, paper, paper products, printing and publishing	1.23	0.84	0.52	0.41	203.4	217.6	171.1	149.4
Coke, refined petroleum products and nuclear fuel	3.93	1.13	0.95	0.83	188.7	212.4	167.2	153.6
Chemicals and chemical products	9.56	11.20	11.70	15.17	4373.5	5627.7	6569.2	7162.8
Rubber and plastics products	4.31	4.36	4.03	5.54	290.7	424.0	491.3	557.5
Other non-metallic mineral products	1.98	2.65	1.85	1.93	258.6	351.4	330.3	322.9
Basic metals and fabricated metal products	2.18	2.64	2.36	1.98	1099.2	1084.4	1142.9	1117.1
Machinery, not elsewhere classified (n.e.c.)	6.07	6.07	6.86	7.13	904.0	1057.2	1198.0	1314.5
Electrical and optical equipment	22.28	21.99	20.88	19.82	6003.3	5892.6	5516.2	5124.6
Transport equipment	3.01	4.24	3.76	5.31	693.6	911.9	954.2	988.1
Manufacturing (n.e.c.); recycling	1.33	1.42	1.80	1.16	82.0	115.3	138.8	128.9
Electricity, gas and water supply	0.03	0.06	0.08	0.11	8.6	20.2	24.3	28.7
Construction	0.35	0.37	0.34	0.36	221.0	299.6	327.9	345.2
Wholesale and retail trade	0.15	0.23	0.25	0.20	125.6	258.0	386.7	411.9
Hotels and restaurants	0.06	0.03	0.06	0.03	8.0	8.6	19.2	16.2
Transport and storage	0.22	0.32	0.27	0.08	96.6	157.5	220.7	183.7
Post and Telecommunications*	0.52	1.49	1.46	2.12	58.9	186.4	449.9	617.2
Financial intermediation	0.19	0.21	0.36	0.51	123.3	169.4	248.7	321.7
Real estate activities	0.01	0.01	0.00	0.00	107.4	52.1	25.4	19.0
Renting of material & equipment and other business activities	1.62	2.58	2.27	2.29	1442.6	3011.2	4342.7	4795.1
Community social and personal services	0.01	0.02	0.03	0.05	12.0	40.7	84.5	123.0

Source: Own computations based on OECD data.
(*) "Post and telecommunications" is reduced to telecommunications for R&D expenditures.

Table 2 provides the R&D intensity of Belgian industries and of industries of the three small European neighbouring countries in the last available year, 2007. The three other countries also have R&D activities highly concentrated in a few sectors and in general in the same sectors as in Belgium. Ireland, however, records R&D intensities largely below the ones of the other countries. As Belgium, Austria and the Netherlands have particularly high R&D intensities in Chemicals and in Electrical and optical equipment. In this last sector, Austria and The Netherlands record higher intensity than Belgium. It is not the case in Chemicals, where Belgium is the most R&D-intensive country. R&D activities of Austria and the Netherlands are also concentrated in Transport equipment, in Machinery not elsewhere classified and for Austria, to a lesser extent in Rubber and plastics products and in Renting of material & equipment and other business, with intensities close to the ones of Belgium (except the Netherlands in Transport equipment, which is largely more intensive than the other countries). R&D intensities in Ireland are concentrated, to a lesser extent than the other countries, in Electrical and optical equipment, in Machinery not elsewhere classified and in Renting of material & equipment and other business.

Table 2 R&D intensity in Belgium, Austria, the Netherlands and Ireland
in % of value added, 2007

	R&D Intensity			
Industry	BE	AUT	NL	IRL
Agriculture, hunting, forestry and fishing	1.08	0.03	0.65	0.04
Mining and quarrying	0.61	0.77	0.57	0.09
Food products, beverages and tobacco	1.48	0.50	2.04	1.28
Textiles, textile products, leather and footwear	2.64	2.32	1.24	0.95
Wood and products of wood and cork	0.59	0.54	0.17	3.13
Pulp, paper, paper products, printing and publishing	0.41	0.76	0.71	0.04
Coke, refined petroleum products and nuclear fuel	0.83	2.14	0.19	0.32
Chemicals and chemical products	15.17	11.41	11.39	2.74
Rubber and plastics products	5.54	5.36	2.32	2.58
Other non-metallic mineral products	1.93	2.54	0.74	0.29
Basic metals and fabricated metal products	1.98	2.43	1.50	1.64
Machinery, not elsewhere classified (n.e.c.)	7.13	8.60	8.49	4.36
Electrical and optical equipment	19.82	24.68	35.81	5.30
Transport equipment	5.31	12.64	5.28	1.26
Manufacturing (n.e.c.); recycling	1.16	3.20	0.26	2.00
Electricity, gas and water supply	0.11	0.14	0.26	0.02
Construction	0.36	0.10	0.08	0.00
Wholesale and retail trade	0.20	0.74	0.28	0.50
Hotels and restaurants	0.03	0.00	0.00	0.00
Transport and storage	0.08	0.07	0.26	0.02
Post and Telecommunications*	2.12	0.97	1.31	0.45
Financial intermediation	0.51	0.06	0.19	0.11
Real estate activities	0.00	0.00	0.00	0.00
Renting of material & equipment and other business activities	2.29	5.06	1.17	3.99
Community social and personal services	0.05	0.02	0.01	0.01

Source: Own computations based on OECD data.
(*) "Post and telecommunications" is reduced to telecommunications for R&D expenditures.

Table 3 provides, for each Belgian industry, the inter-industry domestic R&D stocks and foreign R&D stocks between 1995 and 2007. These stocks are estimated with Supply and Use tables. Inter-industry domestic stocks and foreign stocks vary strongly from one industry to another and are higher in manufacturing industries. At the end of the period, inter-industry domestic stocks are particularly high in Coke, refined petroleum products and nuclear fuel and to a lesser extent in Rubber and plastics and in Manufacturing n.e.c. and recycling. Coke, refined petroleum products and nuclear fuel is the industry using most domestic intermediate inputs relative to value added. It can thus benefit to a larger extent from the R&D in other industries. Rubber and plastics benefited from a higher inter-industry domestic stock at the beginning of the period, but witnessed a decrease of its stock due to a lesser use of R&D-intensive domestic intermediate inputs. All other industries recorded an increase in the inter-industry domestic stock. The increase is important in four industries with small initial stocks: Telecommunications, Chemicals and chemical products, Financial intermediation and Pulp and paper.

Over the whole period, foreign R&D stocks are particularly high in Transport equipment, which uses many imported intermediate inputs containing a lot of R&D activities. To a lesser extent, Coke, Chemicals and Electrical and optical equipment also benefit from an important foreign R&D stock. These sectors are largely dominated by multinational enterprises and correspond to industries in Belgium where the share of R&D expenditures controlled by foreign affiliates are very large.

Nearly all industries recorded an increase in foreign R&D stock, with the exception of Electrical and optical equipment, Electricity, Financial intermediation and Renting of material & equipment and other business. The increase in foreign R&D stock is particularly important in Telecommunications and in Manufacturing n.e.c. and recycling. In services sectors, foreign R&D stocks are generally lower than in manufacturing. That is partly explained by the fact that, due to the availability of imports data, only the spillovers from manufacturing towards services are taken into account.

Table 3 Inter-industry domestic R&D stocks and foreign R&D stocks (SUT-weighted)
millions constant (2000) PPP US dollars

	Inter-industry domestic stocks				Foreign stocks			
Industry	1995	2000	2005	2007	1995	2000	2005	2007
Agriculture, hunting, forestry and fishing	449.2	706.9	1054.8	1043.3	1861.8	2194.0	2391.7	2651.4
Mining and quarrying	318.7	628.4	553.5	615.9	1055.1	836.8	1289.2	1389.7
Food products, beverages and tobacco	516.5	885.9	1011.0	1148.8	1918.0	3553.2	3737.7	3995.6
Textiles, textile products, leather and footwear	831.8	953.7	1119.0	1170.9	8423.6	10136.7	11109.8	12325.2
Wood and products of wood and cork	768.0	912.2	970.1	1030.9	2140.8	3286.7	4116.0	4508.3
Pulp, paper, paper products, printing and publishing	254.5	855.6	933.1	1024.7	1976.0	3269.0	2751.2	2985.1
Coke, refined petroleum products and nuclear fuel	3010.5	3241.2	4728.7	4582.8	41782.5	36550.5	38149.4	42126.0
Chemicals and chemical products	143.0	470.2	628.1	715.1	21641.2	30011.3	27775.8	30841.3
Rubber and plastics products	2560.9	1943.5	1564.1	1562.3	18919.5	19105.5	17289.3	19005.4
Other non-metallic mineral products	344.1	617.0	679.9	723.4	1719.6	2761.6	3194.1	3461.5
Basic metals and fabricated metal products	233.8	511.8	641.8	699.5	4741.6	6474.7	5001.4	5098.3
Machinery, not elsewhere classified (n.e.c.)	439.1	603.4	827.3	882.1	15274.8	16087.7	14729.3	15493.6
Electrical and optical equipment	214.0	748.2	648.3	738.8	28612.2	50488.1	25312.4	25362.2
Transport equipment	414.8	723.0	692.6	758.2	95514.0	108703.8	108178.2	121152.6
Manufacturing (n.e.c.); recycling	551.2	786.4	1588.4	1568.4	1595.0	4019.2	7324.9	7814.4
Electricity, gas and water supply	197.7	225.0	492.3	562.8	2372.4	2324.6	447.3	460.3
Construction	377.2	578.7	792.1	862.5	1734.2	2760.6	1781.6	1827.5
Wholesale and retail trade	313.9	797.3	712.5	819.3	1604.1	5753.9	3673.3	3917.2
Hotels and restaurants	403.7	642.6	1000.7	1110.7	209.3	296.2	470.4	490.8
Transport and storage	225.3	546.0	479.4	547.8	855.3	2386.9	807.4	883.4
Post and Telecommunications*	70.0	409.8	457.7	514.6	45.3	2379.4	1961.5	1963.0
Financial intermediation	105.1	306.2	527.0	620.3	316.8	337.0	54.6	54.7
Real estate activities	69.3	105.5	155.3	177.7	37.9	56.6	42.5	43.2
Renting of material & equipment and other business activities	82.3	99.2	97.6	102.2	873.2	1337.9	644.0	662.9
Community social and personal services	112.1	217.2	297.3	339.0	846.1	1011.5	911.5	994.1

Source: Own computations based on OECD data.
(*) "Post and telecommunications" is reduced to telecommunications for R&D expenditures.

For each industry, the inter-industry domestic R&D stock and the foreign R&D stock depend in fact on a few industries/countries that are important in terms of intermediate consumption for the concerned industry and/or in terms of R&D activities. That is why table 4 lists, for the Belgian industries identified as having important indirect and foreign stocks in table 3[12], the three industries constituting the majority of R&D inter-industry domestic and foreign stocks. For foreign industries, the three countries contributing the most to the foreign stock are also cited. A fourth country is sometimes cited when its contribution is equivalent to the one of the third country. The exercise is realized for the 3 years for which supply and use tables are constructed at a detailed level: 1995, 2000 and 2005[13]. For the inter-industry domestic stock, industries at the origin of spillovers are available in A60 level. For foreign stock, data are available at A31 level.

12 The other sectors are in annex.

13 Input-ouput tables as well as some data included in the SUT are available only every five years. Intermediate SUT between 1995, 2000 and 2005 are estimated with less detailed information.

It appears from table 4 and table 8 in annex that several characteristics are similar in all industries. Two major sectors contribute to the inter-industry domestic stock of the majority of industries: Chemicals excluding pharmaceuticals and Renting of material & equipment and other business. In third position, Wholesale and retail trade is frequently cited. The influence of R&D activities of these three industries is even more important in manufacturing than in services sectors. A lot of sectors use as domestic intermediate inputs a large amount of products from these three industries, and in particular from the two services, Renting of material and equipment and other business and Trade. In addition, the R&D stocks of Chemicals and Renting of material and equipment and other business are very high. A high weight assigned to these industries combined with a high stock lead to a strong presence of these industries in the inter-industry domestic stock.

Next to these three industries, other industries, depending on the nature of the activity of the sector receiving spillovers, constitute inter-industry domestic stock. For example, Agriculture and Hotels and restaurants takes advantage of R&D activities of Food and beverages; Food and beverage benefits from Agriculture ; Machinery, not elsewhere classified from Basic and Fabricated metal and from Electrical machinery and apparatus, nec ; Transport equipment from Electrical machinery and apparatus, nec, Manufacturing (n.e.c.); recycling from Basic metals ; Electricity, gas and water supply from Electrical machinery and apparatus, nec and Construction ; Construction from Other non-metallic mineral and Fabricated metal ; Wholesale and retail trade from Transport and storage ; Transport and storage from Construction and Coke, refined petroleum and nuclear fuel ; Financial intermediation from Post and telecommunications ; Real estate activities from Construction and Financial intermediation ; Community social and personal services from Pharmaceuticals.

The composition of inter-industry domestic stocks between 1995 and 2005 is often relatively similar. The industries benefit often from R&D activities of the same industries between 1995 and 2005. However, the importance of the contribution of each industry may change over time, either because of a change in the intermediate consumption, either because of a change in the evolution of R&D stocks of the industry at the origin of the spillover.

Concerning international stocks, the identified industries may be different from the ones intervening in the inter-industry domestic stock for two reasons. First, the same industry abroad is also taken into account (direct foreign spillovers). Second, due to the availability of imports data, only the foreign manufacturing industries are taken into account as source of international spillovers.

Table 4 and table 8 in annex show that the bulk of Belgian industries benefit from R&D activities of the same sector abroad. The same countries are always identified as source of international spillovers: the neighbouring countries (Germany, France, The Netherlands and the United Kingdom), the United States and Japan. Two industries appear often as source of international spillovers: Chemicals and Chemical products and Electrical and optical equipment because the

imported intermediate consumption of these goods by Belgian industries is often high and because the R&D stocks of these sectors abroad are very important. These two sectors are dominated by multinational enterprises, which can facilitate spillovers between countries. Other industries playing a role in the inter-industry domestic stock also appears in the international level. As for the inter-industry domestic stock, the composition of foreign stocks between 1995 and 2005 is often similar.

Table 4 Composition of inter-industry domestic and foreign stocks by industry (SUT-weighted), 1995-2000-2005

Coke, refined petroleum products and nuclear fuel	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (85.1%)	Renting and business activities (7.8%)	Machinery, nec (2.7%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (75.4%)	Renting and business activities (17.4%)	Wholesale and retail trade (3.9%)
Inter-industry domestic stock 2005	Chemicals (non pharma) (74.9%)	Renting and business activities (19.1%)	Wholesale and retail trade (2.8%)
Foreign stock 1995	Chemicals and chemical products (92.1%): US (37.0%), DE (28.5%), FR (9.2%), UK (9.1%)	Coke, refined petroleum products and nuclear fuel (3.6%): NL (1.6%), US (0.9%), FR (0.6%)	Mining and quarrying (2.1%): UK (1.3%), NL (0.3%), DE (0.3%)
Foreign stock 2000	Chemicals and chemical products (86.1%): US (37.3%), DE (22.8%), UK (9.0%), FR (8.8%)	Mining and quarrying (7.2%): NL (3.1%), UK (2.7%)	Coke, refined petroleum products and nuclear fuel (5.4%): NL (2.3%), FR (1.4%)
Foreign stock 2005	Chemicals and chemical products (91.0%): US (40.5%), DE (23.0%), UK (9.8%), FR (8.6%)	Mining and quarrying (5.0%): NL (2.9%), UK (0.9%), NO (0.8%)	Coke, refined petroleum products and nuclear fuel (2.4%): FR (0.7%), NL (0.6%), UK (0.5%), US (0.4%)

Chemicals and chemical products	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (55.9%)	Wholesale and retail trade (7.7%)	Transport and storage (6.8%)
Inter-industry domestic stock 2000	Renting and business activities (73.7%)	Wholesale and retail trade (8.7%)	Coke, refined petroleum and nuclear fuel (3.2%)
Inter-industry domestic stock 2005	Renting and business activities (73.0%)	Wholesale and retail trade (8.6%)	Coke, refined petroleum and nuclear fuel (3.3%)
Foreign stock 1995	Chemicals and chemical products (98.1%): US (39.4%), DE (30.4%), FR (9.8%), UK (9.7%)	Electrical and optical equipment (0.5%): US (0.2%), DE (0.1%), JP (0.1%)	Machinery, nec (0.4%): DE (0.2%), US (0.1%)
Foreign stock 2000	Chemicals and chemical products (98.4%): US (42.7%), DE (26.1%), UK (10.3%), FR (10.0%)	Electrical and optical equipment (0.4%): US (0.2%), DE (0.1%), JP (0.1%)	Coke, refined petroleum products and nuclear fuel (0.3%): FR (0.1%), NL (0.1%)
Foreign stock 2005	Chemicals and chemical products (95.7%): US (42.6%), DE (24.2%), UK (10.3%), FR (9.1%)	Electrical and optical equipment (2.5%): US (0.9%), DE (0.6%), JP (0.6%)	Machinery, nec (0.5%): DE (0.2%), US (0.2%), JP (0.1%)

Rubber and plastics products	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (95.2%)	Renting and business activities (2.1%)	Wholesale and retail trade (0.9%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (83.1%)	Renting and business activities (10.5%)	Wholesale and retail trade (2.6%)
Inter-industry domestic stock 2005	Chemicals (non pharma) (62.5%)	Renting and business activities (29.0%)	Wholesale and retail trade (2.9%)
Foreign stock 1995	Chemicals and chemical products (97.2%): US (39.1%), DE (30.1%), FR (9.7%), UK (9.6%)	Rubber and plastics products (1.0%): DE (0.3%), FR (0.2%), US (0.2%), JP (0.2%)	Basic metals and fabricated metal products (0.9%): DE (0.4%), US (0.2%), FR (0.1%), JP (0.1%)
Foreign stock 2000	Chemicals and chemical products (85.8%): US (37.2%), DE (22.7%), UK (9.0%), FR (8.7%)	Transport equipment (8.5%): DE (3.4%), US (3.0%)	Rubber and plastics products (3.5%): DE (1.3%), FR (0.8%), US (0.7%)
Foreign stock 2005	Chemicals and chemical products (82.6%): US (36.8%), DE (20.9%), UK (8.9%), FR (7.8%)	Electrical and optical equipment (8.5%): US (3.8%), DE (2.5%), JP (2.2%)	Rubber and plastics products (3.2%): DE (1.1%), JP (0.8%), FR (0.7%), US (0.5%)

Electrical and optical equipment	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Basic metals (44.9%)	Renting and business activities (22.0%)	Chemicals (non pharma) (12.8%)
Inter-industry domestic stock 2000	Renting and business activities (59.8%)	Chemicals (non pharma) (20.0%)	Rubber and plastics (4.7%)
Inter-industry domestic stock 2005	Renting and business activities (71.9%)	Wholesale and retail trade (7.0%)	Chemicals (non pharma) (5.4%)
Foreign stock 1995	Electrical and optical equipment (97.2%): US (36.2%), DE (26.1%), JP (17.6%)	Basic metals and fabricated metal products (1.1%): DE (0.5%), FR (0.2%), US (0.2%)	Chemicals and chemical products (0.9%): DE (0.3%), US (0.3%), FR (0.1%), UK (0.1%)
Foreign stock 2000	Electrical and optical equipment (96.1%): US (40.3%), JP (22.4%), DE (18.8%)	Chemicals and chemical products (2.8%): US (1.2%), DE (0.7%), FR (0.3%), UK (0.3%)	Basic metals and fabricated metal products (0.6%): DE (0.3%), FR (0.1%), US (0.1%)
Foreign stock 2005	Electrical and optical equipment (96.3%): US (36.2%), JP (21.2%), DE (23.7%)	Chemicals and chemical products (2.2%): US (1.0%), FR (0.2%), UK (0.2%)	Basic metals and fabricated metal products (0.8%): DE (0.4%), FR (0.2%), US (0.1%)

Transport equipment	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Electrical machinery and apparatus, nec (21.5%)	Chemicals (non pharma) (18.4%)	Renting and business activities (17.2%)
Inter-industry domestic stock 2000	Renting and business activities (39.1%)	Electrical machinery and apparatus, nec (16.8%)	Wholesale and retail trade (10.6%)
Inter-industry domestic stock 2005	Renting and business activities (43.7%)	Wholesale and retail trade (12.8%)	Electrical machinery and apparatus, nec (12.1%)
Foreign stock 1995	Transport equipment (90.3%): DE (36.6%), US (28.6%), FR (10.0%)	Electrical and optical equipment (8.0%): US (3.0%), DE (2.2%), JP (1.5%)	Chemicals and chemical products (0.7%): US (0.3%), DE (0.2%), FR (0.1%), UK (0.1%)
Foreign stock 2000	Transport equipment (81.5%): DE (32.8%), US (28.6%), FR (8.6%)	Electrical and optical equipment (15.4%): US (6.5%), JP (3.6%), DE (3.0%)	Machinery, nec (1.4%): DE (0.6%), US (0.4%), JP (0.2%), FR (0.1%)
Foreign stock 2005	Transport equipment (81.2%): DE (41.3%), JP (12.9%), FR (10.9%)	Electrical and optical equipment (14.8%): US (5.5%), DE (3.6%), JP (3.3%)	Machinery, nec (2.3%): DE (1.0%), US (0.7%), JP (0.3%)

Manufacturing (n.e.c.); recycling	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Basic metals (31.3%)	Renting and business activities (19.6%)	Chemicals (non pharma) (15.8%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (28.6%)	Basic metals (23.8%)	Renting of material &equipment and other business activities (22.5%)
Inter-industry domestic stock 2005	Chemicals (non pharma) (61.7%)	Renting and business activities (18.3%)	Basic metals (6.7%)
Foreign stock 1995	Basic metals and fabricated metal products (33.9%): DE (15.4%), US (7.3%), FR (5.4%)	Chemicals and chemical products (21.0%): US (8.4%), DE (6.5%), UK (2.1%), FR (2.1%)	Rubber and plastics products (13.3%): DE (4.3%), US (2.9%), FR (2.8%)
Foreign stock 2000	Chemicals and chemical products (34.5%): US (15.0%), DE (9.1%), UK (3.6%), FR (3.5%)	Basic metals and fabricated metal products (19.8%): DE (8.3%), US (4.5%), FR (3.8%)	Transport equipment (17.1%): DE (6.9%), US (6.0%), FR (1.8%)
Foreign stock 2005	Chemicals and chemical products (54.9%): US (24.5%), DE (13.9%), UK (5.9%), FR (5.2%)	Basic metals and fabricated metal products (22.5%): DE (10.1%), US (3.1%), FR (5.7%)	Electrical and optical equipment (13.2%): US (4.9%), DE (3.2%), JP (2.9%)

Inter-industry domestic stocks and foreign stocks presented above are used to estimate potential rent spillovers via intermediate consumption. Table 5 gives, for the Belgian industries, the indirect domestic and foreign R&D stocks over the period 1995-2007 constructed with patent citations matrices in order to estimate potential knowledge spillovers. The last year for which the patents citations matrix is available is 2003, which is why this year is given in the table instead of 2005. After 2003, weights from the 2003 matrix are applied to construct R&D stocks.

The most important stocks are found for the two categories of stocks in manufacturing industries. Indirect domestic stocks and foreign stocks are particularly high in Machinery, not elsewhere classified and Electrical and optical equipment. Chemicals and chemical products also benefit from very high foreign stocks and high indirect domestic stocks. To a lesser extent, Wood, Rubber and plastics products and Manufacturing (n.e.c.); recycling and Transport equipment for foreign stocks also have relatively high levels of both stocks in comparison with the other sectors.

Over the whole period, Transport equipment and Construction recorded the strongest growth of indirect domestic stocks. The strongest growth of foreign stocks is observed in Community social and personal services, in Electricity, gas and water supply, in Food products, beverages and tobacco and in Agriculture. These strong growths of stocks are often associated with small stocks in 1995.

Table 5 Indirect domestic R&D stocks and foreign R&D stocks (patent citations matrices-weighted)
millions constant (2000) PPP USD

	Indirect domestic stocks				Foreign stocks			
Industry	1995	2000	2003	2007	1995	2000	2003	2007
Agriculture, hunting, forestry and fishing	0.9	1.2	1.3	1.5	34.0	47.3	53.1	76.7
Mining and quarrying	0.0	0.0	0.0	0.0	2.9	5.7	4.1	5.7
Food products, beverages and tobacco	3.3	3.7	5.6	6.3	196.5	249.9	305.5	427.2
Textiles, textile products, leather and footwear	2.6	3.4	3.8	4.0	415.2	331.6	395.9	455.5
Wood and products of wood and cork	30.1	23.8	31.4	32.6	2357.7	2284.9	2727.5	3079.7
Pulp, paper, paper products, printing and publishing	12.9	8.2	15.3	16.5	682.3	778.8	847.4	965.3
Coke, refined petroleum products and nuclear fuel	1.5	1.2	0.6	0.7	91.7	72.5	68.7	96.6
Chemicals and chemical products	29.1	35.1	30.0	28.6	16589.1	14813.5	13419.1	18618.3
Rubber and plastics products	16.5	18.8	18.9	20.3	1778.5	1759.2	1814.0	2153.3
Other non-metallic mineral products	3.9	3.9	4.2	4.4	414.4	362.9	438.1	507.4
Basic metals and fabricated metal products	4.2	5.7	6.6	7.0	687.4	772.3	816.9	928.3
Machinery, not elsewhere classified (n.e.c.)	61.7	59.8	65.2	66.1	9559.1	12403.0	10976.1	12379.2
Electrical and optical equipment	25.8	26.4	37.8	43.0	19265.2	27275.3	26883.1	29118.6
Transport equipment	1.8	6.5	8.0	8.1	1477.2	2168.0	1912.0	2096.1
Manufacturing (n.e.c.); recycling	30.1	23.8	31.3	32.5	2357.7	2284.9	2727.5	3079.7
Electricity, gas and water supply	0.0	0.0	0.0	0.0	1.2	2.3	3.2	3.5
Construction	0.3	0.1	1.2	1.3	17.2	18.2	29.8	33.4
Trade	0.0	0.0	0.1	0.1	4.2	6.4	4.1	4.9
Hotels and restaurants	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport and storage	0.0	0.0	0.0	0.0	0.3	0.9	0.4	0.5
Post and telecommunications*	0.0	0.0		0.0	3.2	2.1	1.2	1.3
Financial intermediation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Real estate activities, renting of material &equipment and other business activities	1.1	1.0	0.3	0.3	65.4	24.7	20.5	22.7
Community social and personal services	0.5	0.3	0.9	0.9	5.8	6.5	19.8	22.2

* This industry is reduced to telecommunications (without post) for R&D expenditures.

The two following matrices present the distribution by country of patents cited by Belgian industries in 1995 and 2003, the last year for which the patents citations matrix is available. The citations of patents by Belgium correspond to patents useful for developing the new technology

in the Belgian industries and may be seen as a flow of knowledge from the cited country towards the citing Belgian sector. In these two matrices, the cited patents are aggregated by country, without specifying the industry of patent. The total number of citations by Belgium industries sets to 100.

It appears from Table 6 that the majority of citations are made by manufacturing industries, and particularly by the industries indentified as having high indirect and foreign stocks in table 5: Chemicals, Machinery nec, Electrical and optical equipment, Wood and Manufacturing nec. This observation is coherent with the construction of data since these citations are used as weights to estimate indirect and foreign R&D stocks. Apart from Belgium, the United States, Japan and Germany are the most cited countries as source of knowledge spillovers.

Between 1995 and 2003, the number of cited patents in the United States (in the total of citations by Belgium) has decreased from 41.6 % of total citations to 33.3%. The importance of Japan and Germany has increased from respectively 11.3% to 13.4% and from 8.9% to 11.6%. Citations of Belgian patents have also decreased from 20.2% to 17.6%. Concerning Belgian industries citing patents, the importance of Chemicals as citing industries has decreased from 34.6% to 26.2% to the benefit of the other large industries.

Table 6 Patent citations matrices, 1995-2003

1995 (in %)	AT	BE	CZ	DE	DK	ES	FI	FR	GB	GR	IE	IT	NL	PL	PT	SE	US	JP	Other	**Total**
Agriculture, hunting, forestry and fishing	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	**0.09**
Mining and quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
Food products, beverages and tobacco	0.01	0.15	0.00	0.05	0.01	0.00	0.02	0.03	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.28	0.01	0.09	**0.75**
Textiles, textile products, leather and footwear	0.00	0.44	0.00	0.07	0.00	0.00	0.00	0.15	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.50	0.06	0.03	**1.31**
Wood; Medical, precision and optical instruments ; Manufacturing (n.e.c.); recycling	0.02	3.28	0.00	1.08	0.05	0.01	0.01	0.41	0.33	0.00	0.00	0.09	0.33	0.00	0.00	0.19	5.83	1.87	0.65	**14.15**
Pulp, paper, paper products, printing and publishing	0.00	0.56	0.00	0.13	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.11	0.03	0.00	0.00	0.01	0.75	0.45	0.22	**2.33**
Coke, refined petroleum products and nuclear fuel	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.09	0.02	0.00	**0.24**
Chemicals and chemical products	0.09	8.98	0.01	2.12	0.81	0.05	0.08	0.89	1.24	0.00	0.00	0.57	0.83	0.00	0.00	0.17	14.61	2.84	1.30	**34.59**
Rubber and plastics products	0.03	0.64	0.00	0.57	0.03	0.06	0.01	0.19	0.12	0.00	0.00	0.07	0.22	0.00	0.00	0.04	1.94	0.50	0.24	**4.66**
Other non-metallic mineral products	0.01	0.24	0.00	0.19	0.00	0.02	0.01	0.10	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.36	0.22	0.05	**1.25**
Basic metals and fabricated metal products	0.02	0.29	0.00	0.52	0.01	0.02	0.01	0.15	0.10	0.00	0.00	0.04	0.05	0.00	0.00	0.04	0.70	0.19	0.16	**2.29**
Machinery, not elsewhere classified (n.e.c.)	0.10	2.94	0.01	2.24	0.08	0.04	0.14	0.54	0.69	0.03	0.00	0.36	0.36	0.00	0.00	0.16	7.46	2.17	1.30	**18.62**
Electrical and optical equipment (without Medical, precision and optical instruments)	0.07	2.39	0.00	1.32	0.07	0.01	0.10	0.37	0.58	0.00	0.00	0.21	0.24	0.00	0.00	0.24	8.11	2.71	0.84	**17.26**
Transport equipment	0.00	0.15	0.00	0.57	0.00	0.01	0.00	0.14	0.09	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.80	0.23	0.15	**2.18**
Electricity, gas and water supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Construction	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.01	**0.10**
Wholesale and retail trade	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**0.01**
Real estate, renting and business activities	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00	**0.13**
Community social and personal services	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**
Total	**0.35**	**20.19**	**0.03**	**8.91**	**1.07**	**0.24**	**0.40**	**3.03**	**3.30**	**0.03**	**0.01**	**1.49**	**2.19**	**0.00**	**0.00**	**0.87**	**41.54**	**11.32**	**5.05**	**100.00**

2003 (in %)	AT	BE	CZ	DE	DK	ES	FI	FR	GB	GR	IE	IT	NL	PL	PT	SE	US	JP	Other	**Total**
Agriculture, hunting, forestry and fishing	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.01	0.02	**0.12**
Mining and quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
Food products, beverages and tobacco	0.00	0.22	0.00	0.03	0.02	0.08	0.00	0.06	0.01	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.37	0.06	0.10	**1.02**
Textiles, textile products, leather and footwear	0.00	0.20	0.00	0.19	0.00	0.00	0.00	0.05	0.04	0.00	0.01	0.03	0.07	0.00	0.00	0.02	0.29	0.07	0.08	**1.07**
Wood; Medical, precision and optical instruments ; Manufacturing (n.e.c.); recycling	0.05	2.91	0.00	1.74	0.12	0.01	0.07	0.50	0.40	0.00	0.05	0.11	0.49	0.00	0.02	0.16	4.50	2.70	1.17	**15.00**
Pulp, paper, paper products, printing and publishing	0.00	0.66	0.00	0.20	0.00	0.00	0.00	0.08	0.06	0.00	0.00	0.02	0.05	0.00	0.01	0.03	0.44	0.74	0.10	**2.40**
Coke, refined petroleum products and nuclear fuel	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.07	0.01	0.01	**0.16**
Chemicals and chemical products	0.11	6.08	0.08	2.16	0.17	0.11	0.16	1.19	1.27	0.02	0.05	0.27	0.97	0.00	0.00	0.15	9.33	2.32	1.74	**26.19**
Rubber and plastics products	0.05	0.95	0.00	0.62	0.01	0.01	0.04	0.21	0.14	0.00	0.03	0.10	0.19	0.00	0.01	0.10	1.40	0.55	0.33	**4.75**
Other non-metallic mineral products	0.01	0.24	0.00	0.27	0.00	0.01	0.00	0.06	0.02	0.00	0.00	0.03	0.06	0.00	0.00	0.05	0.34	0.11	0.06	**1.28**
Basic metals and fabricated metal products	0.02	0.37	0.00	0.40	0.00	0.02	0.03	0.11	0.13	0.00	0.00	0.02	0.10	0.00	0.00	0.09	0.78	0.15	0.24	**2.46**
Machinery, not elsewhere classified (n.e.c.)	0.09	3.24	0.03	3.00	0.09	0.08	0.12	0.59	0.67	0.00	0.02	0.26	0.76	0.00	0.00	0.24	6.44	2.64	1.74	**20.01**
Electrical and optical equipment (without Medical, precision and optical instruments)	0.06	1.72	0.01	1.90	0.11	0.04	0.24	0.59	0.66	0.00	0.02	0.13	0.90	0.01	0.00	0.28	8.51	3.53	2.65	**21.37**
Transport equipment	0.02	0.87	0.00	1.06	0.00	0.01	0.01	0.18	0.08	0.00	0.00	0.06	0.04	0.00	0.02	0.03	0.76	0.47	0.24	**3.83**
Electricity, gas and water supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Construction	0.00	0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.05	0.00	0.00	0.01	0.03	0.00	0.02	**0.23**
Wholesale and retail trade	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
Real estate, renting and business activities	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	**0.03**
community social and personal services	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**0.05**
Total	**0.42**	**17.62**	**0.12**	**11.63**	**0.53**	**0.38**	**0.67**	**3.64**	**3.50**	**0.03**	**0.19**	**1.04**	**3.75**	**0.01**	**0.08**	**1.15**	**33.33**	**13.38**	**8.54**	**100.00**

Source: Huub Meijers, UNU-MERIT, own calculations.

Notes: Due to the fact that the matrices are available by Nemesis sectors, Wood (NACE DD) is associated with Medical, precision and optical instruments (NACE 33 in DL) and Manufacturing (n.e.c.); recycling (NACE DN). Hotels and restaurants, Transport and storage, Post and Telecommunications and Financial intermediation are not included in the table because their total is 0.00.

To identify which industries and countries are a potential source of knowledge spillovers for Belgian industries, table 7 gives, for the Belgian manufacturing industries identified as having important indirect and foreign stocks in table 5, the three industries responsible for the majority of these indirect and foreign R&D stocks. The exercise is realized for 1995 and 2003, the last year for which patent citations matrices are available.

According to the composition of stocks, the Belgian industries profit the most from the knowledge of Chemicals and chemical products, from Electrical and optical equipment and to a lesser extent from Machinery, not elsewhere classified (n.e.c.) in Belgium and abroad. These are the three sectors for which the patent citations as knowledge source are the highest in Belgium and abroad. A high weight is consequently assigned to these sectors in the construction of inter-industry domestic and foreign stock. Moreover, these sectors are themselves very intensive in R&D activities. Chemicals and chemical products and Electrical and optical equipment are two sectors dominated by multinational enterprises, which can facilitate spillovers between countries. The most cited countries as source of knowledge are those identified in table 6 over the patent citations distribution: the United States, Japan and Germany.

Between 1995 and 2003, few changes concerning the cited industries are observed. At the level of cited countries, it appears that the United States contribute less to the foreign stocks in 2003 than in 1995 for the benefit of Japan and Germany. It is linked to the decreasing weight given to this country according to the patent citations matrices.

The industries identified as potential source of knowledge spillovers also appear as important potential sources of rent spillovers via SUT tables. With patent citations matrices, manufacturing industries are essentially cited as source of spillovers while with SUT tables, services sectors also appear as important source of rent spillovers.

Table 7 Composition of inter-industry domestic and foreign stocks by industry (patent citations matrices-weighted), 1995-2003

Wood and products of wood and cork	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Electrical and optical equipment (56.8%)	Chemicals and chemical products (37.4%)	Machinery, n.e.c. (4.0%)
Inter-industry domestic stock 2003	Chemicals and chemical products (54.7%)	Electrical and optical equipment (37.8%)	Machinery, n.e.c. (4.6%)
Foreign stock 1995	Electrical and optical equipment (72.0%): US (57.2%), JP (11.2%), DE (2.5%)	Chemicals and chemical products (19.5%): US (15.6%), JP (2.9%), DE (0.5%)	Machinery, n.e.c. (3.7%): US (2.3%), JP (0.9%), DE (0.5%)
Foreign stock 2003	Electrical and optical equipment (74.6%): US (53.7%), JP (16.7%), DE (3.2%)	Chemicals and chemical products (15.0%): US (10.4%), JP (3.1%), DE (0.8%)	Machinery, n.e.c. (5.7%): US (2.7%), JP (2.0%), DE (0.8%)

Chemicals and chemical products	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Electrical and optical equipment (76.2%)	Machinery, n.e.c. (15.9%)	Rubber and plastics products (2.0%)
Inter-industry domestic stock 2003	Electrical and optical equipment (68.1%)	Machinery, n.e.c. (20.7%)	Rubber and plastics products (3.7%)
Foreign stock 1995	Chemicals and chemical products (87.0%): US (74.3%), JP (6.5%), DE (3.3%)	Electrical and optical equipment (9.6%): US (7.5%), JP (1.7%), DE (0.3%)	Machinery, n.e.c. (1.8%): US (1.2%), DE (0.3%), JP (0.3%)
Foreign stock 2003	Chemicals and chemical products (80.1%): US (65.2%), JP (5.9%), DE (4.2%)	Electrical and optical equipment (14.9%): US (10.6%), JP (3.6%), DE (0.5%)	Machinery, n.e.c. (3.5%): US (2.3%), JP (0.8%), DE (0.3%)

Rubber and plastics products	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals and chemical products (60.8%)	Electrical and optical equipment (32.5%)	Machinery, n.e.c. (3.7%)
Inter-industry domestic stock 2003	Chemicals and chemical products (61.4%)	Electrical and optical equipment (21.8%)	Machinery, n.e.c. (9.8%)
Foreign stock 1995	Electrical and optical equipment (43.9%): US (34.9%), JP (5.2%), DE (3.1%)	Chemicals and chemical products (37.5%): US (31.0%), JP (3.7%), DE (2.0%)	Transport equipment (7.3%): US (6.3%), DE (0.4%), JP (0.4%)
Foreign stock 2003	Electrical and optical equipment (49.8%): US (37.0%), JP (9.8%), DE (2.0%)	Chemicals and chemical products (29.7%): US (22.7%), JP (4.0%), DE (1.8%)	Machinery, n.e.c. (8.4%): US (4.8%), DE (1.8%), JP (1.4%)

Machinery, not elsewhere classified	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Electrical and optical equipment (54.8%)	Chemicals and chemical products (41.8%)	Basic metals and fabricated metal products (1.2%)
Inter-industry domestic stock 2003	Chemicals and chemical products (48.3%)	Electrical and optical equipment (45.4%)	Transport equipment (2.1%)
Foreign stock 1995	Electrical and optical equipment (67.3%): US (54.9%), JP (9.4%), DE (2.0%)	Machinery, n.e.c. (12.5%): US (7.9%), DE (2.2%), JP (2.0%)	Chemicals and chemical products (12.2%): US (9.8%), JP (1.3%), DE (0.7%)
Foreign stock 2003	Machinery, n.e.c. (65.1%): US (49.5%), JP (12.3%), DE (2.3%)	Machinery, n.e.c. (14.7%): US (8.3%), DE (3.1%), JP (2.9%)	Chemicals and chemical products (11.9%): US (9.3%), JP (1.5%), DE (0.7%)

Electrical and optical equipment	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals and chemical products (72.9%)	Machinery, n.e.c. (21.3%)	Rubber and plastics products (1.2%)
Inter-industry domestic stock 2003	Chemicals and chemical products (78.4%)	Machinery, n.e.c. (14.5%)	Transport equipment (2.6%)
Foreign stock 1995	Electrical and optical equipment (90.0%): US (73.1%), JP (13.1%), DE (2.5%)	Machinery, n.e.c. (4.1%): US (2.8%), JP (0.8%), DE (0.4%)	Chemicals and chemical products (3.8%): US (2.9%), JP (0.6%), DE (0.2%)
Foreign stock 2003	Electrical and optical equipment (90.9%): US (72.5%), JP (14.7%), DE (2.4%)	Machinery, n.e.c. (3.9%): US (2.3%), JP (1.0%), DE (0.4%)	Chemicals and chemical products (3.3%): US (2.3%), JP (0.7%), DE (0.2%)

Transport equipment	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals and chemical products (37.2%)	Electrical and optical equipment (34.8%)	Machinery, n.e.c. (20.5%)
Inter-industry domestic stock 2003	Electrical and optical equipment (46.9%)	Machinery, n.e.c. (24.3%)	Chemicals and chemical products (19.3%)
Foreign stock 1995	Transport equipment (66.7%): US (50.4%), DE (10.9%), JP (3.3%)	Electrical and optical equipment (22.9%): US (17.4%), DE (2.6%), JP (2.4%)	Machinery, n.e.c. (6.2%): US (3.5%), DE (1.5%), JP (1.0%)
Foreign stock 2003	Transport equipment (61.5%): US (29.2%), DE (22.5%), JP (7.3%)	Electrical and optical equipment (24.0%): US (14.1%), JP (6.9%), DE (2.5%)	Machinery, n.e.c. (9.9%): US (4.8%), DE (3.2%), JP (1.6%)

Manufacturing (n.e.c.); recycling	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Electrical and optical equipment (57.0%)	Chemicals and chemical products (37.5%)	Machinery, n.e.c. (4.0%)
Inter-industry domestic stock 2003	Chemicals and chemical products (54.8%)	Electrical and optical equipment (37.9%)	Machinery, n.e.c. (4.6%)
Foreign stock 1995	Electrical and optical equipment (72.0%): US (57.2%), JP (11.2%), DE (2.5%)	Chemicals and chemical products (19.5%): US (15.6%), JP (2.9%), DE (0.5%)	Machinery, n.e.c. (3.7%): US (2.3%), JP (0.9%), DE (0.5%)
Foreign stock 2003	Electrical and optical equipment (74.6%): US (53.7%), JP (16.7%), DE (3.2%)	Chemicals and chemical products (15.0%): US (10.4%), JP (3.1%), DE (0.8%)	Machinery, n.e.c. (5.7%): US (2.7%), JP (2.0%), DE (0.8%)

5. Conclusions

Research and Development (R&D) activities are generally considered as one of the main determinants of productivity growth. Not only own R&D activities may affect innovation and productivity growth of firms, but also R&D performed by other domestic or foreign firms (R&D spillovers). Griliches (1979) distinguishes two categories of spillovers: rent spillovers, occurring when R&D intensive inputs are purchased at less than their full "quality" price, and knowledge spillovers, corresponding to the transfer of ideas between firms.

To test for the presence of R&D spillovers in Belgium[17], the construction of direct, inter-industry domestic and foreign stocks is necessary. That is the objective of this Working Paper.

Direct, Inter-industry domestic and foreign stocks are presented at an industry-level over the period 1995-2007. Direct stocks are computed according to the perpetual inventory method on the basis of R&D expenditures in constant prices. Two categories of stocks are constructed to estimate potential rent spillovers and knowledge spillovers. To estimate rent spillovers, Belgian inter-industry R&D stocks are weighted with Supply and Use tables, while foreign stocks are weighted with SUT and bilateral trade data. These stocks have the objective to measure, for each Belgian industry, the R&D activities realised in other industries in Belgium (inter-industry domestic stock) and in industries abroad (foreign stock) that may have an impact on the considered industry through its intermediate consumption.

To estimate knowledge spillovers, inter-industry domestic and foreign R&D stocks were constructed using international patent citations matrices. A patent citation can be related to a knowledge flow from the cited country/industry to the citing country/industry.

Data show that, in Belgium, R&D activity is highly concentrated in two knowledge-intensive manufacturing industries: Chemicals and chemical products and Electrical and optical equipment. R&D stock is also relatively high in Renting of material and equipment and other business activities in the services sector.

Inter-industry domestic stocks and foreign stocks, estimated with SUT tables, vary strongly from one industry to another and are higher in manufacturing industries. At the end of the period, inter-industry domestic stocks are particularly high in Coke and to a lesser extent in Rubber and plastics and in Manufacturing n.e.c and recycling. Over the whole period, foreign R&D stocks are particularly high in Transport equipment, which uses a lot of imported intermediate inputs containing a lot of R&D activities. To a lesser extent, Coke, Chemicals and Electrical and optical equipment also benefit from an important foreign R&D stock. These sectors are characterised by an important presence in Belgium of enterprises under foreign control.

For each industry, the inter-industry domestic R&D stock and the foreign R&D stock depend on a few industries/countries that are important in terms of intermediate consumption for the concerned in-

[17] That was the objective of de Working Paper: B. Biatour, Dumont, M., Kegels, C. (2011), "The determinants of industry-level total factor productivity in Belgium", Federal Planning Bureau, WP 7-11.

dustry and/or in terms of R&D activities. Two major sectors contribute to the inter-industry domestic stock of a lot of industries: Chemicals excluding pharmaceuticals and Renting of material & equipment and other business. In third position, Wholesale and retail trade appears frequently.

The same countries are always identified as source of international spillovers: the neighbouring countries (Germany, France, The Netherlands and the United Kingdom), the United States and Japan. Two industries appear often as source of international spillovers: Chemicals and Chemical products and Electrical and optical equipment because the imported intermediate consumption of these goods by Belgian industries is often high and because the R&D stocks of these sectors abroad are very important. These two sectors are dominated by multinational enterprises, which can facilitate spillovers between countries. A lot of Belgian industries also benefit from R&D activities of the same sector abroad.

To estimate potential knowledge spillovers, indirect domestic and foreign R&D stocks are constructed with patent citations matrices. Over the period 1995-2007, indirect domestic stocks and foreign stocks are particularly high in Machinery, not elsewhere classified and Electrical and optical equipment. Chemicals and chemical products also benefit from very high foreign stocks and high indirect domestic stocks. To a lesser extent, Wood, Rubber and plastics products and Manufacturing n.e.c.; recycling have also relatively high levels of both stocks in comparison with the other sectors.

The Belgian industries profit the most from the knowledge of Chemicals and chemical products, from Electrical and optical equipment and to a lesser extent from Machinery, not elsewhere classified in Belgium and abroad. These are the three sectors for which the patent citations as knowledge source are the highest in Belgium and abroad. The most cited countries as source of knowledge are the United States, Japan and Germany.

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7. Annexe

Table 8 Composition of inter-industry domestic and foreign stocks by industry (SUT-weighted), 1995-2000-2005

Agriculture, hunting, forestry and fishing	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Food and beverages (44.2%)	Chemicals (non pharma) (27.2%)	Machinery, nec (13.6%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (47.0%)	Food and beverages (30.0%)	Renting and business activities (6.0%)
Inter-industry domestic stock 2005	Chemicals (non pharma) (52.5%)	Food and beverages (26.7%)	Renting and business activities (7.6%)
Foreign stock 1995	Chemicals and chemical products (62.3%): US (25.1%), DE (19.3%), FR (6.2%), UK (6.1%)	Machinery, nec (29.2%): DE (16.0%), US (5.4%), JP (2.8%)	Food products, beverages and tobacco (5.5%): FR (2.0%), NL (1.5%), US (0.8)
Foreign stock 2000	Chemicals and chemical products (57.1%): US (24.8%), DE (15.1%), UK (5.9%), FR (5.8%)	Machinery, nec (36.1%): DE (15.3%), US (11.47%), JP (4.3%)	Food products, beverages and tobacco (2.9%): FR (1.1%), NL (0.8%)
Foreign stock 2005	Chemicals and chemical products (87.5%): US (39.0%), DE (22.1%), UK (9.4%), FR (8.3%)	Machinery, nec (5.4%): DE (2.4%), US (1.6%), JP (0.7%)	Transport equipment (3.0%): DE (1.5%), JP (0.5%), FR (0.4%)

Mining and quarrying	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Machinery, nec (32.1%)	Chemicals (non pharma) (28.1%)	Renting and business activities (17.9%)
Inter-industry domestic stock 2000	Renting and business activities (61.1%)	Chemicals (non pharma) (13.6%)	Machinery, nec (9.3%)
Inter-industry domestic stock 2005	Renting and business activities (64.8%)	Chemicals (non pharma) (7.8%)	Wholesale and retail trade (6.5%)
Foreign stock 1995	Machinery, nec (62.5%): DE (34.3%), US (11.5%), JP (6.1%)	Chemicals and chemical products (18.8%): US (7.6%), DE (5.8%), FR (1.9%), UK (1.9%)	Mining and quarrying (8.0%): UK (4.8%), NL (1.3%), DE (1.0%)
Foreign stock 2000	Chemicals and chemical products (57.1%): US (19.2%), DE (11.7%), UK (4.6%), FR (4.5%)	Machinery, nec (36.6%): DE (15.5%), US (11.6%), JP (4.4%)	Mining and quarrying (6.3%): NL (2.7%), UK (2.4%)
Foreign stock 2005	Chemicals and chemical products (54.0%): US (24.0%), DE (13.6%), UK (5.8%), FR (5.1%)	Machinery, nec (28.8%): DE (12.2%), US (8.4%), JP (3.4%)	Electrical and optical equipment (8.5%): US (3.2%), DE (2.1%), JP (1.9%)

Food products, beverages and tobacco	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (39.5%)	Agriculture, hunting, forestry and fishing (33.6%)	Chemicals (non pharma) (8.7%)
Inter-industry domestic stock 2000	Renting and business activities (50.8%)	Agriculture, hunting, forestry and fishing (22.0%)	Chemicals (non pharma) (9.2%)
Inter-industry domestic stock 2005	Renting and business activities (59.1%)	Agriculture, hunting, forestry and fishing (11.5%)	Wholesale and retail trade (10.3%)
Foreign stock 1995	Food products, beverages and tobacco (39.6%): FR (14.2%), NL (11.0%), US (5.8%)	Chemicals and chemical products (34.0%): US (13.7%), DE (10.5%), FR (3.4%), UK (3.4%)	Agriculture, hunting, forestry and fishing (9.8%): FR (5.9%), NL (1.7%), DE (1.1%)
Foreign stock 2000	Chemicals and chemical products (57.5%): US (24.9%), DE (15.2%), UK (6.0%), FR (5.8%)	Food products, beverages and tobacco (26.1%): FR (9.6%), NL (7.2%)	Agriculture, hunting, forestry and fishing (5.2%): FR(3.5%), NL(1.0%)
Foreign stock 2005	Chemicals and chemical products (52.7%): US (23.5%), DE (13.3%), UK (5.7%), FR (5.0%)	Food products, beverages and tobacco (24.8%): FR (11.0%), NL (6.4%), DE (3.5%)	Machinery, nec (6.4%): DE (2.8%), US (1.9%), JP (0.8%)

Textiles, textile products, leather and footwear	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (77.9%)	Renting and business activities (10.7%)	Wholesale and retail trade (3.0%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (57.9%)	Renting and business activities (25.8%)	Wholesale and retail trade (7.2%)
Inter-industry domestic stock 2005	Chemicals (non pharma) (44.4%)	Renting and business activities (40.8%)	Wholesale and retail trade (6.5%)
Foreign stock 1995	Chemicals and chemical products (92.3%): US (37.1%), DE (28.6%), FR (9.2%), UK (9.1%)	Textiles, leather and footwear (3.6%): DE (1.1%), FR (1.0%), US (0.8%)	Machinery, nec (2.3%): DE (1.3%), US (0.4%), UK (0.2%), JP (0.2%)
Foreign stock 2000	Chemicals and chemical products (93.4%): US (40.5%), DE (24.7%), UK (9.7%), FR (9.5%)	Textiles, leather and footwear (3.0%): DE (1.1%), FR (0.9%)	-
Foreign stock 2005	Chemicals and chemical products (92.4%): US (41.2%), DE (23.3%), UK (9.9%), FR (8.8%)	Textiles, leather and footwear (2.4%): DE (1.0%), FR (0.7%), US (0.2%), IT (0.1%)	Machinery, nec (2.3%): DE (1.0%), US (0.7%), JP (0.3%)

Wood and products of wood and cork	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (73.9%)	Renting and business activities (9.5%)	Agriculture, hunting, forestry and fishing(5.0%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (56.5%)	Renting and business activities (23.7%)	Wholesale and retail trade (8.2%)
Inter-industry domestic stock 2005	Renting and business activities (41.5%)	Chemicals (non pharma) (34.4%)	Wholesale and retail trade (10.5%)
Foreign stock 1995	Chemicals and chemical products (69.1%): US (27.8%), DE (21.4%), FR (6.9%), UK (6.8%)	Machinery, nec (15.2%): DE (8.4%), US (2.8%), JP (1.5%)	Wood (3.9%): DE (2.4%), US (0.8%), FR (0.3%)
Foreign stock 2000	Chemicals and chemical products (85.0%): US (36.9%), DE (22.5%), UK (8.9%), FR (8.6%)	Rubber and plastics products (3.5%): DE (1.3%), FR (0.8%), US (0.7%), JP (0.6%)	Wood (2.8%): DE (1.3%), US (0.9%)
Foreign stock 2005	Chemicals and chemical products (80.0%): US (35.6%), DE (20.2%), UK (8.6%), FR (7.6%)	Electrical and optical equipment (7.0%): US (2.6%), DE (1.7%), JP (1.5%)	Machinery, nec (3.9%): DE (1.7%), US (1.2%), JP (0.5%)

Pulp, paper, paper products, printing and publishing	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (58.0%)	Renting and business activities (23.8%)	Wholesale and retail trade (3.9%)
Inter-industry domestic stock 2000	Renting and business activities (43.8%)	Chemicals (non pharma) (42.5%)	Wholesale and retail trade (5.4%)
Inter-industry domestic stock 2005	Renting and business activities (60.2%)	Chemicals (non pharma) (26.0%)	Wholesale and retail trade (5.1%)
Foreign stock 1995	Chemicals and chemical products (74.1%): US (29.8%), DE (22.9%), FR (7.4%), UK (7.3%)	Paper, printing and publishing (12.5%): US (4.5%), DE (2.2%), FR (1.6%)	Machinery, nec (4.9%): DE (2.7%), US (0.9%), JP (0.5%)
Foreign stock 2000	Chemicals and chemical products (78.2%): US (33.9%), DE (20.7%), UK (8.2%), FR (8.0%)	Paper, printing and publishing (14.9%): US (8.6%), DE (2.0%), FR (1.4%)	Rubber and plastics products (3.8%): DE (1.4%), FR (0.8%), US (0.7%), JP (0.6%)
Foreign stock 2005	Chemicals and chemical products (72.1%): US (32.1%), DE (18.2%), UK (7.7%), FR (6.8%)	Paper, printing and publishing (16.3%): US (8.4%), DE (3.2%), FR (1.7%)	Machinery, nec (4.8%): DE (2.1%), US (1.4%), JP (0.6%)

Other non-metallic mineral products	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (40.6%)	Renting and business activities (26.1%)	Basic metals (11.4%)
Inter-industry domestic stock 2000	Renting and business activities (38.0%)	Chemicals (non pharma) (36.6%)	Wholesale and retail trade (6.6%)
Inter-industry domestic stock 2005	Renting and business activities (45.2%)	Chemicals (non pharma) (30.6%)	Wholesale and retail trade (9.6%)
Foreign stock 1995	Chemicals and chemical products (65.9%): US (26.5%), DE (20.4%), FR (6.6%), UK (6.5%)	Machinery, nec (12.4%): DE (6.8%), US (2.3%), JP (1.2%)	Other non-metallic mineral products (8.1%): DE (2.8%), FR (1.8%), US (1.4%), JP (1.3%)
Foreign stock 2000	Chemicals and chemical products (72.3%): US (31.3%), DE (19.1%), UK (7.5%), FR (7.4%)	Other non-metallic mineral products (7.7%): DE (3.0%), FR (1.9%), US (1.1%), JP (1%)	Machinery, nec (5.4%): DE (2.3%) US (1.7%)
Foreign stock 2005	Chemicals and chemical products (72.3%): US (32.2%), DE (18.3%), UK (7.8%), FR (6.8%)	Electrical and optical equipment (7.1%): US (2.7%), DE (1.8%), JP (1.6%)	Machinery, nec (7.1%): DE (3.1%) US (2.1%), JP (0.9%)

Basic metals and fabricated metal products	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (43.0%)	Renting and business activities (28.1%)	Electrical machinery and apparatus, nec (5.2%)
Inter-industry domestic stock 2000	Renting and business activities (43.0%)	Chemicals (non pharma) (29.3%)	Wholesale and retail trade (10.0%)
Inter-industry domestic stock 2005	Renting and business activities (48.1%)	Chemicals (non pharma) (20.3%)	Wholesale and retail trade (12.7%)
Foreign stock 1995	Basic metals and fabricated metal products (62.1%): DE (28.2%), US (13.5%), FR (9.9%)	Electrical and optical equipment (19.7%): US (7.4%), DE (5.3%), JP (3.6%)	Chemicals and chemical products (12.0%): US (4.8%), DE (3.7%), FR (1.2%), UK (1.2%)
Foreign stock 2000	Basic metals and fabricated metal products (53.8%): DE (22.5%), FR (10.2%), US (12.2%)	Electrical and optical equipment (18.9%): US (7.9%), JP (4.4%), DE (3.7%)	Chemicals and chemical products (16.8%): US (7.3%), DE (4.4%), FR (1.7%), UK (1.7%)
Foreign stock 2005	Basic metals and fabricated metal products (53.8%): DE (24.2%), FR (13.5%), US (7.4%)	Chemicals and chemical products (22.1%): US (9.8%), DE (5.6%), UK (2.4%), FR (2.1%)	Electrical and optical equipment (14.8%): US (5.6%), DE (3.6%), JP (3.3%),

Machinery, not elsewhere classified (n.e.c.)	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Basic metals (21.2%)	Renting and business activities (15.8%)	Electrical machinery and apparatus, nec (14.3%)
Inter-industry domestic stock 2000	Renting and business activities (44.3%)	Fabricated metal (19.5%)	Electrical machinery and apparatus, nec (9.3%)
Inter-industry domestic stock 2005	Renting and business activities (40.3%)	Chemicals (non pharma) (13.2%)	Basic metals (11.6%)
Foreign stock 1995	Electrical and optical equipment (34.1%): US (12.7%), DE (9.2%), JP (6.2%)	Machinery, nec (30.4%): DE (16.7%), US (5.6%), JP (3.0%)	Transport equipment (29.6%): DE (12.0%), US (9.4%), FR (3.3%)
Foreign stock 2000	Machinery, nec (37.9%): DE (16.1%), US (12.1%), JP (4.5%)	Electrical and optical equipment (37.6%): US (15.8%), JP (8.8%), DE (7.3%)	Transport equipment (18.9%): DE (7.6%), US (6.6%), FR (2.0%)
Foreign stock 2005	Machinery, nec (42.4%): DE (18.5%), US (12.6%), JP (5.2%)	Electrical and optical equipment (34.6%): US (13.0%), DE (8.5%), JP (7.6%),	Transport equipment (16.0%): DE (8.2%), JP (2.6%), FR (2.2%)

Electricity, gas and water supply	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Electrical machinery and apparatus, nec (28.7%)	Renting and business activities (22.7%)	Chemicals (non pharma) (11.6%)
Inter-industry domestic stock 2000	Renting and business activities (52.5%)	Electrical machinery and apparatus, nec (18.2%)	Construction (9.9%)
Inter-industry domestic stock 2005	Renting and business activities (71.8%)	Construction (5.9%)	Chemicals (non pharma) (4.2%)
Foreign stock 1995	Electrical and optical equipment (92.9%): US (34.6%), DE (25.0%), JP (16.9%)	Chemicals and chemical products (3.0%): US (1.2%), DE (0.9%), FR (0.3%), UK (0.3%)	Machinery, nec (1.6%): DE (0.9%), US (0.3%), JP (0.2%)
Foreign stock 2000	Electrical and optical equipment (92.4%): US (38.8%), JP (21.6%), DE (18.0%)	Machinery, nec (4.2%): DE (1.8%), US (1.4%), JP (0.5%)	Chemicals and chemical products (1.6%): US (0.7%), DE (0.4%), FR (0.2%), UK (0.2%)
Foreign stock 2005	Electrical and optical equipment (53.8%): US (20.2%), DE (13.3%), JP (11.9%)	Chemicals and chemical products (20.7%): US (9.2%), DE (5.2%), UK (2.2%), FR (2.0%)	Machinery, nec (10.5%): DE (4.6%), US (3.1%), JP (1.3%)

Construction	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (28.1%)	Renting and business activities (21.4%)	Other non-metallic mineral (17.2%)
Inter-industry domestic stock 2000	Renting and business activities (37.3%)	Other non-metallic mineral (13.6%)	Fabricated metal (10.1%)
Inter-industry domestic stock 2005	Renting and business activities (47.3%)	Chemicals (non pharma) (11.7%)	Fabricated metal (8.7%)
Foreign stock 1995	Electrical and optical equipment (74.8%): US (27.9%), DE (20.1%), JP (13.6%)	Chemicals and chemical products (10.3%): US (4.1%), DE (3.2%), FR (1.0%), UK (1.0%)	Basic metals and fabricated metal products (5.7%): DE (2.6%), US (1.2%), FR (0.9%)
Foreign stock 2000	Electrical and optical equipment (72.7%): US (30.5%), JP (17.0%), DE (14.2%)	Chemicals and chemical products (8.7%): US (3.8%), DE (2.3%), FR (0.9%), UK (0.9%)	Basic metals and fabricated metal products (7.4%): DE (3.1%), US (1.7%), FR (1.4%)
Foreign stock 2005	Electrical and optical equipment (53.4%): US (20.1%), DE (13.2%), JP (11.8%)	Chemicals and chemical products (18.7%): US (8.3%), DE (4.7%), UK (2.0%)	Basic metals and fabricated metal products (11.2%): DE (5.0%), FR (2.8%), US (1.5%)

Wholesale and retail trade	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (70.6%)	Chemicals (non pharma) (13.5%)	Transport and storage (5.6%)
Inter-industry domestic stock 2000	Renting and business activities (74.1%)	Chemicals (non pharma) (9.3%)	Construction (3.5%)
Inter-industry domestic stock 2005	Renting and business activities (85.8%)	Transport and storage (4.9%)	Post and telecommunications (2.2%)
Foreign stock 1995	Chemicals and chemical products (58.8%): US (23.6%), DE (18.2%), FR (5.9%), UK (5.8%)	Transport equipment (15.7%): DE (6.4%), US (5.0%), FR (1.7%)	Electrical and optical equipment (14.9%): US (5.6%), DE (4.0%), JP (2.7%)
Foreign stock 2000	Chemicals and chemical products (37.0%): US (16.1%), DE (9.8%), UK (3.9%), FR (3.8%)	Electrical and optical equipment (36.6%): US (15.4%), JP (8.6%), DE (7.2%),	Transport equipment (16.3%): DE (6.6%), US (5.7%), FR (1.7%)
Foreign stock 2005	Electrical and optical equipment (41.1%): US (15.4%), DE (10.1%), JP (9.1%),	Chemicals and chemical products (29.2%): US (13.0%), DE (7.4%), UK (3.1%), FR (2.8%),	Transport equipment (20.2%): DE (10.3%), FR (2.7%), JP (3.2%)

Hotels and restaurants	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Food and beverages (47.5%)	Renting and business activities (37.2%)	Chemicals (non pharma) (7.1%)
Inter-industry domestic stock 2000	Food and beverages (42.7%)	Renting and business activities (38.6%)	Chemicals (non pharma) (5.8%)
Inter-industry domestic stock 2005	Renting and business activities (52.3%)	Food and beverages (36.3%)	Wholesale and retail trade (3.5%)
Foreign stock 1995	Food products, beverages and tobacco (50.4%): FR (18.0%), NL (14.0%), US (7.4%)	Chemicals and chemical products (26.9%): US (10.8%), DE (8.3%), FR (2.7%), UK (2.7%)	Basic metals and fabricated metal products (11.9%): DE (5.4%), US (2.6%), FR (1.9%)
Foreign stock 2000	Food products, beverages and tobacco (55.9%): FR (20.6%), NL (15.3%), DE (6.6%), US (6.2%)	Chemicals and chemical products (25.4%): US (11.0%), DE (6.7%), UK (2.7%), FR (2.6%)	Electrical and optical equipment (8%): US (3.4%), JP (1.9%), DE (1.6%)
Foreign stock 2005	Food products, beverages and tobacco (52.5%): FR (23.2%), NL (13.5%), DE (7.4%)	Chemicals and chemical products (34.0%): US (15.1%), DE (8.6%), UK (3.6%), FR (3.2%)	Electrical and optical equipment (5.0%): US (1.9%), DE (1.2%), JP (1.1%),

Transport and storage	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (52.5%)	Construction (14.10%)	Chemicals (non pharma) (10.0%)
Inter-industry domestic stock 2000	Renting and business activities (73.5%)	Construction (6.4%)	Coke, refined petroleum and nuclear fuel (4.8%)
Inter-industry domestic stock 2005	Renting and business activities (75.2%)	Coke, refined petroleum and nuclear fuel (5.2%)	Wholesale and retail trade (4.4%)
Foreign stock 1995	Transport equipment (69.1%): DE (28.0%), US (21.9%), FR (7.6%)	Chemicals and chemical products (8.5%): US (3.4%), DE (2.6%), UK (0.8%), FR (0.8%)	Electrical and optical equipment (7.8%): US (2.9%), DE (2.1%), JP (1.4%)
Foreign stock 2000	Transport equipment (92.1%): DE (37.0%), US (32.3%), FR (9.7%)	Coke, refined petroleum products and nuclear fuel (2.3%): NL (1.0%), FR (0.6%), UK (0.3%), US (0.3%)	Chemicals and chemical products (2.2%): US (1.0%), DE (0.6%), FR (0.2%), UK (0.2%)
Foreign stock 2005	Transport equipment (57.8%): DE (29.4%), JP (9.2%), FR (7.8%)	Electrical and optical equipment (21.3%): US (8.0%), DE (5.3%), JP (4.7%)	Rubber and plastics products (6.5%): DE (2.2%), JP (1.5%), FR (1.4%)

Post and telecommunications*	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (65.4%)	Chemicals (non pharma) (12.9%)	Transport and storage (6.3%)
Inter-industry domestic stock 2000	Renting and business activities (81.7%)	Chemicals (non pharma) (5.2%)	Telecommunication equipment (4.3%)
Inter-industry domestic stock 2005	Renting and business activities (75.6%)	Radio, television and communication equipment (12.5%)	Wholesale and retail trade (2.9%)
Foreign stock 1995	Chemicals and chemical products (39.4%): US (15.8%), DE (12.2%), FR (3.9%), UK (3.9%)	Coke, refined petroleum products and nuclear fuel (29.7%): NL (13.5%), US (7.2%), FR (5.3%)	Machinery, nec (14.4%): DE (7.9%), US (2.6%), JP (1.4%)
Foreign stock 2000	Electrical and optical equipment (96.7%): US (40.6%), JP (22.6%), DE (18.9%)	Chemicals and chemical products (2.9%): US (1.2%), DE (0.8%), FR (0.3%), UK (0.3%)	-
Foreign stock 2005	Electrical and optical equipment (97.2%): US (36.5%), DE (24.0%), JP (21.4%)	Basic metals and fabricated metal products (0.9%): DE (0.4%), FR (0.2%), US (0.1%)	Chemicals and chemical products (0.8%): US (0.3%), DE (0.2%), FR (0.1%), UK (0.1%)

Financial intermediation	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (78.7%)	Chemicals (non pharma) (6.8%)	Construction (3.1%)
Inter-industry domestic stock 2000	Renting and business activities (93.9%)	Post and telecommunications (2.6%)	Construction (0.6%)
Inter-industry domestic stock 2005	Renting and business activities (94.8%)	Post and telecommunications (3.7%)	Transport and storage (0.4%)
Foreign stock 1995	Electrical and optical equipment (91.5%): US (34.1%), DE (24.6%), JP (16.6%)	Chemicals and chemical products (4.7%): US (1.9%), DE (1.5%), FR (0.5%)	Basic metals and fabricated metal products (2.6%): DE (1.2%), US (0.6%), FR (0.4%)
Foreign stock 2000	Electrical and optical equipment (96.6%): US (40.5%), JP (22.6%), DE (18.8%)	Basic metals and fabricated metal products (1.6%): DE (0.7%), US (0.4%), FR (0.3%)	Paper, printing and publishing (0.9%): US (0.5%), FR (0.1%), DE (0.1%)
Foreign stock 2005	Electrical and optical equipment (88.2%): US (33.1%), DE (21.7%), JP (19.5%)	Basic metals and fabricated metal products (4.0%): DE (1.8%), FR (1.0%), US (0.6%),	Paper, printing and publishing (3.5%): US (1.8%), DE (0.7%), FR (0.4%),

Real estate activities	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Construction (28%)	Renting and business activities (23.5%)	Financial intermediation (15.2%)
Inter-industry domestic stock 2000	Renting and business activities (45.6%)	Construction (38.6%)	Financial intermediation (7.4%)
Inter-industry domestic stock 2005	Renting and business activities (61.4%)	Construction (20.3%)	Financial intermediation (9.5%)
Foreign stock 1995	Chemicals and chemical products (63.3%): US (25.5%), DE (19.6%), FR (6.3%), UK (6.2%)	Basic metals and fabricated metal products (13.4%): DE (6.1%), US (2.9%), FR (2.1%)	Other non-metallic mineral products (11.0%): DE (3.7%), FR (2.5%), US (1.9%), JP (1.7%)
Foreign stock 2000	Electrical and optical equipment (79.1%): US (33.2%), JP (18.5%), DE (15.4%)	Chemicals and chemical products (12.7%): US (5.5%), DE (3.4%), FR (1.3%), UK (1.3%)	Basic metals and fabricated metal products (3.1%): DE (1.3%), US (0.7%), FR (0.6%)
Foreign stock 2005	Electrical and optical equipment (53.3%): US (20.0%), JP (11.8%), DE (13.1%)	Chemicals and chemical products (11.7%): US (5.2%), DE (3.0%), UK (1.3%), FR (1.1%)	Basic metals and fabricated metal products (10.3%): DE (4.6%), FR (2.6%), US (1.4%)

Renting of material &equipment and other business activities	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Chemicals (non pharma) (45.5%)	Financial intermediation (12.9%)	Printing, publishing and reproduction (11.8%)
Inter-industry domestic stock 2000	Chemicals (non pharma) (35.6%)	Coke, refined petroleum and nuclear fuel (13.9%)	Financial intermediation (11.9%)
Inter-industry domestic stock 2005	Chemicals (non pharma) (31.5%)	Post and telecommunications (14.3%)	Financial intermediation (9.7%)
Foreign stock 1995	Electrical and optical equipment (73.7%): US (27.5%), DE (19.8%), JP (13.4%)	Chemicals and chemical products (19.8%): US (8.0%), DE (6.1%), UK (2.0%), FR (2.0%)	Basic metals and fabricated metal products (1.6%): DE (0.7%), US (0.4%), FR (0.3%)
Foreign stock 2000	Electrical and optical equipment (59.1%): US (24.8%), JP (13.8%), DE (11.5%)	Chemicals and chemical products (22.8%): US (9.9%), DE (6.0%), UK (2.4%), FR (2.3%)	Transport equipment (14.2%): DE (5.7%), US (5.0%), FR (1.5%)
Foreign stock 2005	Electrical and optical equipment (70.2%): US (26.4%), DE (17.3%), JP (15.5%)	Chemicals and chemical products (24.5%): US (10.9%), DE (6.2%), UK (2.6%), FR (2.3%)	Machinery, nec (1.7%): DE (0.7%), US (0.5%), JP (0.2%), FR (0.1%)

Community social and personal services	Industry 1	Industry 2	Industry 3
Inter-industry domestic stock 1995	Renting and business activities (37.4%)	Pharmaceuticals (21.8%)	Chemicals (non pharma) (18.5%)
Inter-industry domestic stock 2000	Renting and business activities (44.1%)	Pharmaceuticals (20.0%)	Chemicals (non pharma) (18.8%)
Inter-industry domestic stock 2005	Renting and business activities (58.5%)	Pharmaceuticals (18.1%)	Chemicals (non pharma) (9.6%)
Foreign stock 1995	Chemicals and chemical products (40.2%): US (16.2%), DE (12.4%), FR (4.0%), UK (4.0%)	Electrical and optical equipment (38.3%): US (14.3%), DE (10.3%), JP (7.0%)	Transport equipment (19.7%): DE (8.0%), US (6.2%), FR (2.2%)
Foreign stock 2000	Electrical and optical equipment (42.4%): US (17.8%), JP (9.9%), DE (8.3%)	Chemicals and chemical products (53.8%): US (23.3%), DE (14.2%), UK (5.6%), FR (5.5%)	Transport equipment (1.8%): DE (0.7%), US (0.6%), FR (0.2%)
Foreign stock 2005	Chemicals and chemical products (72.3%): US (32.2%), DE (18.3%), UK (7.8%), FR (6.8%)	Electrical and optical equipment (20.0%): US (7.5%), DE (4.9%), JP (4.4%)	Transport equipment (4.3%): DE (2.2%), JP (0.7%), FR (0.6%)