SECTORAL PRODUCTIVITY GROWTH AND R&D SPILLOVERS IN THE NETHERLANDS

BY

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Summary

This paper assesses empirically whether R&D spillovers are important and whether they originate from domestic or foreign activities. Data for eleven sectors are used to explain the impact on total factor productivity of R&D by the sector itself, by other Dutch sectors and by foreign sectors. We find that both domestic and foreign R&D are significant for the Dutch economy. The elasticity of total factor productivity with respect to R&D is approximately 37% for R&D by a sector, 15% for R&D by other Dutch sectors and 3% for R&D by foreign sectors. Our findings suggest moreover that more R&D speeds up the adoption of foreign technologies. Thus, even for a small open economy as the Netherlands, promoting investment in R&D is appropriate as it both stimulates adoption and generates spillovers.

Key words: R&D spillovers, productivity growth

1 INTRODUCTION[1]

Economic policy in the Netherlands aims at structurally improving the economy. For example, labour market institutions have been reformed. In addition, emphasis is placed on growth-enhancing policies such as investment in public infrastructure, education and training, and R&D. The success of these growth-enhancing policies is not obvious. The larger part of public investment consists of infrastructure projects. Whether the return on large-scale infrastructure projects is high or low is difficult to assess. Furthermore, not much research has been de-

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voted to other potentially growth-promoting policies such as public support for R&D investment. The structural effects of R&D on the Dutch economy are far from clear. Exactly this is the central issue in this paper.

A general concern is that investment in innovative products and production methods is too low in the Netherlands. Dutch R&D expenditures are low by international standards. This is even true when one accounts for differences in the sectoral structure. Table 1 compares sectoral R&D intensities in various countries. The Netherlands has an internationally weak ranking in R&D-intensive sectors, such as Chemicals and Metal. An exception is the strong position of the Netherlands in Food, compared with competitors abroad. However, the overall impression is that Dutch sectors are at the lower end of the distribution.

Comparatively low R&D investments do not necessarily imply that the government should stimulate these investments. Growth theories, however, express the concern for under-investment.[2] These theories emphasize the externalities associated with R&D and suggest that public policy should bring the private return of R&D in line with the social return, thereby stimulating economic growth and raising welfare. These theoretical insights, together with the observation that the Netherlands do comparatively little R&D, suggest that the government should stimulate investment in new technologies.

A sceptic, on the other hand, might argue that the gains from government interference should not be overestimated. Policies to stimulate R&D may very well run into the usual implementation problems. For example, governments may not want to subsidise R&D across the board and thus face the problem how to select potentially successful projects. Conceivably, instruments to promote R&D imply serious problems, eroding or even dwarfing their potential gains. Another important issue is that the scope of R&D spillovers is not necessarily national, but could very well be international. This seems relevant for a small open economy and especially for the Netherlands, where multinational firms have a significant share in aggregate R&D expenditures. If domestic R&D spills over mainly to foreign firms, it is no longer clear that promoting R&D is an optimal policy.[3]

However, strong international spillovers do not imply that the public and the private sector should just 'wait for things to happen.' Economic policy may aim to speed up the assimilation of foreign technologies. A well trained labour force may facilitate the introduction of new products and new production technologies that have been developed elsewhere.[4] R&D may have a similar role to play. The rate of economic growth may increase because R&D directly spurs the development of new products and new, more efficient production methods. Increased

2 See for example Romer (1986, 1990) and Grossman and Helpman (1991, chapter 3). Under-investment in R&D is not necessarily the outcome in the Grossman and Helpman model (see de Groot and Nahuis (1998)).

3 See Leahy and Neary (1999) for a systematic analysis of national and international spillovers.

4 A discussion on human capital, and the role it plays in technology assimilation, is provided in Jacobs et al. (2000).

TABLE 1 – R&D INTENSITY IN 1992 (R&D EXPENDITURE, % OF VALUE ADDED)*

	Netherlands	Germany	Japan	USA	UK	Sweden	Canada	Denmark	Finland	France	Italy	*unweighted average*
Chemicals Petroleum	8.6	8.3	13.2	10.4	11.7	15.7	4.8	10.4	9.2	8	6.4	*8.9*
Metal	4.6	6.2	5.6	10.9	6	9.7	3.7	5.6	4.6	7.1	3.9	*5.8*
Food	1.9	0.5	1.9	1.3	1.4	1.5	0.5	1.3	3	1.1	0.3	*1.2*
Textile	0.8	0.7	5	0.5	0.4	0.8	1.0	0.6	1.8	0.6	0	*1.0*
Wood	0.8	2.4	–	1.7	2.9	0.9	0.6	1.4	2.7	3.6	0.3	*1.5*
Public Utilities	0.2	–	1.0	0.2	1.6	–	1.3	0.2	2.4	1.5	0.8	*0.8*
Other Services	0.1	–	–	–	0.5	–	0.6	0.8	0.2	0.1	0.2	*0.2*
Construction	0.1	–	0.6	–	0.1	–	0.0	0.2	0.2	0.3	0.0	*0.1*
Paper	0.1	0.4	2.4	1.1	0.3	2.2	0.7	0.2	2.2	0.4	0.0	*0.9*

Sources: OECD; ISDB and ANBERD databases.
* See section 4 for a detailed description of the sectors and data.

R&D activities may also boost growth indirectly, because these activities speed up the assimilation of already existing technologies developed outside the domestic economy (see Cohen and Levinthal (1989)).

A clear-cut policy advice does not emerge from this discussion, but the empirical questions are clear. First, what is the impact of domestic R&D expenditure on the performance of the Dutch economy? Second, are spillovers important and are they predominantly national or international?

This paper empirically assesses the role of domestic and foreign R&D in the process of technological change. It combines an analysis at a sectoral level with the approach emanating from Coe and Helpman (1995). We follow Coe and Helpman in examining international trade as a vehicle for the transmission of spillovers. More specifically, data for eleven sectors are pooled to estimate the impact on total factor productivity of R&D by a sector itself, by other Dutch sectors, and by foreign sectors. This allows us to answer the question whether externalities are important in the process of economic growth and whether spillovers are predominantly national or international.

We find that both domestic and foreign R&D are important for the Dutch economy. The elasticity of total factor productivity with respect to R&D is 37% for R&D by a sector, 15% for R&D by other Dutch sectors, and 3% for R&D by foreign sectors. Our findings also suggest that more R&D speeds up the absorption of foreign technologies. Disaggregating the economy into manufacturing and services confirms these results. To understand the low (at least in comparison to other findings) effect of foreign R&D it is important to notice that we do not restrict ourselves to manufacturing but focus on the aggregate economy. This, along with the fact that even in the Netherlands the import intensity is low,[5] makes international trade an understandably weak knowledge transmission vehicle.

The rest of this paper is organised as follows. The next section (selectively) reviews and discusses some of the earlier empirical studies. In section 3 we derive an empirical model that builds on a theoretical framework. Section 4 gives an overview of the data and characterises the sectors under consideration. The main empirical findings are presented in section 5. The last section concludes and gives possible directions for future research.

2 DETECTING R&D SPILLOVERS

R&D is often considered one of the main determinants of economic growth. The introduction of better products and production technologies boosts productivity, not only in the innovating sector but potentially also in other sectors. The benefits of R&D in one sector spill over to the other sectors. These spillovers must be taken into account when assessing the impact of R&D on sectoral productivity.[6]

R&D spillovers might, as discussed in the introduction, call for an active government policy. Jones and Williams (1998) assess the size of the market failure, i.e. the difference between the social and private returns on R&D investment. Accepting 30% as a lower-bound estimate for the social rate of return, they claim that the United States should quadruple expenditure on R&D (see Nadiri (1993) for an overview of estimated returns).[7] Their claim is staggering but not necessarily implausible. At the very least it shows that growth theories seriously suggest an active role for governments: they should stimulate R&D investment to spur the development of new technologies.

The literature is also concerned with the channels along which R&D raises productivity. In this context Grilliches (1979) distinguishes spillovers related to imperfect appropriation of rents from R&D (and imperfect measurement of true prices by statistical agencies) and 'technical' knowledge spillovers. Imperfect appropriation is related to the use of intermediate inputs. R&D activity of input

5 Most industries import far less than 50% of their gross production value. This point is discussed more extensively in section 4.

6 This discussion of the literature is sketchy and only intends to position this paper. Recent, more comprehensive overviews are provided by Griliches (1992), Nadiri (1993), and Mohnen (1996).

7 The reported rate of return is a lower-bound estimate as externalities over time are usually ignored (these turn out to be unambiguously positive).

suppliers increases the quality of inputs. Competition may keep these suppliers from raising prices so as to fully reflect quality improvements. That is, the innovating sectors cannot fully appropriate the benefits of their R&D activities. Upstream industries benefit from R&D effort by downstream industries; rents of R&D spill over according to input-output (IO) relations. In the remainder we refer to these spillovers as rent spillovers. Accordingly, a measure for rent spillovers can be constructed by weighting the R&D stocks of other sectors with the intermediate deliveries by these sectors.[8] The rationale for this procedure has been explained and discussed before by, for example, Griliches and Lichtenberg (1984).

Pure knowledge spillovers are benefits of R&D activities of one firm that accrue to another. More precisely, a sector's R&D enhances the efficiency of other sector's output production or R&D activity. Knowledge spillovers can arise in many different ways and are not necessarily a by-product of intermediate deliveries. For example, a firm can learn and increase its productivity by observing efforts of other firms – in the same or a different sector.

The degree to which R&D in a sector is relevant for other sectors depends on the transmission mechanism. With respect to knowledge spillovers a so-called technology-flow matrix is usually postulated. Technology flow matrices are sometimes constructed from IO data (see Sakurai et al. (1997), Wolff (1997)). Somewhat confusingly, intermediate deliveries among sectors are then vehicles for both knowledge and rent spillovers. More often, transmission matrices for knowledge spillovers are based on patent applications or patent citations. Scherer (1982) originally proposed this approach. Several matrices based on patent data exist, such as the well-known 'Yale' matrix (van Meijl (1995) and Keller (1997)). Technology flow approaches are present in many variations (Jaffe (1986), Verspagen (1997a, 1997b), and Los and Verspagen (1996)). Los (1997) compares different IO-based and patent-based matrices and finds little variation in the estimated long-run elasticities.[9]

Less extensive is the literature dealing with the question whether spillovers are national or international in scope.[10] Most influential is the paper by Coe and Helpman (1995) that analyses international spillovers at a country level.[11] They

8 Alternatively, a capital flow matrix can be employed to capture rent spillovers from investment goods, see Sakurai et al. (1997).

9 Keller uses an IO and technology-flow specification. The qualitative results are similar except for domestic spillovers. The coefficient for domestic spillovers is considerably lower with a technology-flow matrix.

10 Bernstein and Mohnen (1994) are among the exceptions. They use industry data but do not examine the role for national spillovers *alongside* international spillovers.

11 Lichtenberg and Pottelsberghe de la Potterie (1998) reexamine the estimated equations and the construction of foreign R&D stocks, and Engelbrecht (1997) tests the robustness of the results by introducing a human capital variable and a catch-up factor. In light of critique on the seminal work of Coe and Helpman an important result of Engelbrecht is the robustness of the results to the estimation method. Estimations in log difference yield similar and significant results to the estimation of the cointegrated relations. Coe et al. (1997) focus on global North-South knowledge spillovers.

find substantial technological spillovers among OECD countries. The elasticity of total factor productivity with respect to foreign R&D, embodied in traded goods, is about 6%.[12] Park (1995) also examines country-level data. Labour productivity growth is explained by domestic R&D and foreign R&D weighted by technological distance. The elasticity of weighted foreign R&D is 17-18% compared to 11% for domestic R&D.[13] Branstetter (1996) analyses spillovers between Japan and the United States. Domestic and foreign R&D stocks are a weighted sum of R&D expenditures of other firms, where the weights have been constructed on the basis of a technological distance matrix. The main finding is that national spillovers overwhelm international spillovers. Keller (1997) uses data for all OECD countries and applies an IO weighting scheme. R&D in the same sector abroad turns out to have an equally strong effect on TFP as R&D carried out by the sector itself. Verspagen (1997) follows a more or less similar approach as Keller and finds roughly equal effects for foreign and domestic spillovers. Summarizing, researchers have found strong evidence for spillovers but do not agree whether national or international spillovers are more important.

Some researchers have used data on patents to uncover (knowledge) spillovers. Eaton and Kortum (1995) develop a theory to explain patent applications for a single invention in different countries. Combining this theory with data on the number and the cost of patent applications, they are able to distill the perceived probability that an un-patented invention is imitated: the higher this probability, the more important international spillovers. Eaton and Kortum find a strong role for international spillovers. Jaffe et al. (1993) analyse the geography of patent citations. In the United States patents are likely to be cited by firms at a location close to the inventor's location. Across the border citations are less likely than domestic citations. So, spillovers are found but seem to be geographically bounded.

Soete and ter Weel (1999) focus on the Netherlands, but restrict themselves to the manufacturing sector whereas we include service sectors. Their analysis differs in several other respects: the application of a technology-flow matrix implies a focus on pure knowledge spillovers. Moreover, following Verspagen (1997) they estimate production functions with labour productivity as dependent variable. Most importantly, the independent variables are constructed differently.[14] They find an elasticity of foreign spillovers that exceeds the 'own' as well as the domestic spillover elasticity.

12 In their preferred estimation – an estimation that amplifies openness as a catalyst for spillovers – the relevant elasticity for the Netherlands is approximately 15%.

13 Park also compares public and private R&D, and he examines spillovers in research by examining the effect of R&D spillovers on R&D spending. Foreign (public) R&D stimulates domestic R&D.

14 Their constructs are sensitive to aggregation; we discuss this so-called aggregation bias more extensively later. Moreover, they introduce in the domestic indirect knowledge stock an openness factor that make R&D spillovers from closed sectors weighted relatively heavy.

The brief overview of relevant empirical literature shows that researchers have employed various approaches; they have used different estimation methods, dependent variables, explanatory variables, data sets and so on. Not surprisingly, different researchers have arrived at different conclusions. This paper does and cannot immediately change this but is intended to add to our understanding of R&D spillovers. Important is the distinction between spillovers within a sector and within the national economy, i.e. among sectors. Also, extremely relevant for a small open economy is the distinction between national and international spillovers. For a small open economy like the Netherlands it is unclear whether it should stimulate R&D. Finally, the analysis does not focus on manufacturing alone but also includes service sectors.

3 A MODEL OF (INTERNATIONAL) SPILLOVERS

In this section we derive our regression model to analyse the relation between R&D and sectoral productivity growth where we allow both for national and international spillovers.

Production of a sector (indexed i) displays constant returns to scale with respect to primary and intermediate inputs together (X, indexed h, and W, indexed j, respectively). Moreover, production is a function of the technology level (A),

$$Y_i = A_i(.)F_i(X_h, W_j)\,, \quad i, j \in \{1, \dots, N\}\,,\ h \in \{L, K\}\,. \tag{1}$$

First-order conditions for the optimal input choice can be manipulated (assuming competitive input and output markets[15] to determine cost shares (c):

$$\begin{aligned} &\frac{\partial F_i}{\partial X_{hi}}\,\frac{X_{hi}}{F_i} = \frac{P_h X_{hi}}{Y_i} = c_{hi}\,, \quad i \in \{1, \dots, N\}\,,\ h \in \{L, K\}\,, \\ &\frac{\partial F_i}{\partial W_{ji}}\,\frac{W_{ji}}{F_i} = \frac{P_j W_{ji}}{Y_i} = c_{ji}\,, \quad i, j \in \{1, \dots, N\}\,, \end{aligned} \tag{2}$$

where the Ps are relative prices, with the output price as numeraire and $\sum_j c_{ji} + \sum_h c_{hi} = 1$. Taking logs and a first-order approximation for (1) gives,

$$\Delta y_i = \Delta a_i + \sum_h c_{hi}\Delta x_{hi} + c_{ii}\Delta w_{ii} + \sum_{j=1,\, j \neq i}^{N} c_{ji}\Delta w_{ji}\,, \tag{3}$$

15 R&D expenditures – to be discussed later – are included in X, L and K. What we measure is an excess return.

where lowercase variables indicate a logarithm of the original variable, i.e. $\ln A \equiv a$. The third term on the right-hand side denotes intermediate deliveries of firms within a sector to other firms in that same sector.

The measured price indices for intermediate expenditure (P^o) deviate from ideal price indices (P).[16] Typically, the measured indices underestimate quality improvements in intermediate inputs. We assume that intermediate expenditure (e) is measured correctly, $e^o = e$. When deflating expenditures on intermediates the flow of real services from intermediate inputs is underestimated. The difference between properly measured and imputed services from intermediate inputs is:

$$\Delta w_{ji} - \Delta w_{ji}^o = (\Delta e_{ji} - \Delta p_j) - (\Delta e_{ji}^o - \Delta p_j^o) = \Delta p_j^o - \Delta p_j \equiv m_j\,, \tag{4}$$

where m_j is the measurement error. So, the imputed services underestimate the real services if ideal price indices decline faster than the actual price indices (hence $\Delta w_{ji} \neq \Delta w_{ji}^o$). Therefore measured TFP (T) differs from actual TFP (A), due to erroneous measurement of prices:

$$\begin{aligned} \Delta t_i &= \Delta y_i - c_{hi}\Delta x_{hi} - c_{ii}(\Delta e_{ii} - \Delta p_i^o) - \sum_{j=1,\, j\neq i}^{N} c_{ji}(\Delta e_{ij} - \Delta p_j^o)\,, \\ &= \Delta a_i + c_{ii}\, m_{ii} + \sum c_{ji}\, m_j \end{aligned} \tag{5}$$

The measurement error originates from the difficulty to assess quality improvements in intermediate inputs. The degree of mismeasurement depends on a measure for quality improvements. Such a measure for quality improvements is R&D activity in the supplying industry. The errors are therefore approximated by the growth of R&D stocks (R, the discounted sum of previous investments), $m_j = \theta_j \Delta r_j$, where θ is the parameter linking R&D efforts to quality improvements. Combining this with equation (5) yields,

$$\Delta t_i = \Delta a_i + \theta c_{ii}\Delta r_i + \sum_{j=1,\, j\neq i}^{N} \theta_j c_{ji}\Delta r_j\,, \tag{6}$$

Hence, measured TFP growth in an industry is a function of actual TFP growth and changes in R&D stocks in the own and other industries. The exposition on the impact of R&D growth on TFP growth suggests how to construct variables to capture spillovers by IO relations.

We construct the R&D spillover stocks as follows. The growth rates of R&D stocks of other Dutch sectors ($j \neq i$) are weighted with the intermediate deliveries by these sectors to create a sector-specific domestic R&D stock (R_i^d),[17]

16 The superscript o should be read as *observed.*

17 R&D stocks are created from R&D expenditures by a perpetual inventory method with a depreciation rate of 15%, see Appendix A for more details.

$$\frac{R^d_{i,t} - R^d_{i,t-1}}{R^d_{i,t-1}} = \sum_{j=1, j \neq i}^{N} c_{ji,t} \frac{R_{j,t} - R_{j,t-1}}{R_{j,t-1}}. \tag{7}$$

c_{ji} is the share of intermediate inputs from sector j in total production of sector i. The construction of the foreign stock R^f_i is similar:

$$\frac{R^f_{i,t} - R^f_{i,t-1}}{R^f_{i,t-1}} = \sum_{k=1}^{K} \sum_{j=1, j \neq i}^{N} c_{ji,t} b_{kj,t} \frac{R_{kj,t} - R_{kj,t-1}}{R_{kj,t-1}}. \tag{8}$$

were b_{kj} is the share of country $k \in \{1, \ldots, K\}$ in total Dutch imports of goods produced by sector j.[18] Note that this is an approximation. The reason is that data for bi-lateral trade do not distinguish between intermediate and final goods. Nor are imports of goods distinguished by industry of use.

The construction of indirect R&D stocks based on weighted growth rates deserves some elaboration. Weighting levels of the various R&D stocks is *not* appropriate for the following reasons. First by weighting these stocks, the changes in the weights also matter. Hence, a shift towards inputs from a sector in a large country – with a large R&D stock – would imply an increase in total factor productivity. This implication is implausible. Changes in trade patterns should not necessarily imply significant changes in productivity. Second, a weighting procedure based on levels of R&D stocks suffers from a serious aggregation bias. Lichtenberg and Van Pottelsberghe de la Potterie (1998) point at this aggregation bias in the work of Coe and Helpman. Their solution to eliminate the bias is only insensitive to aggregation under strong restrictions. Similarly, in our approach this bias is absent if some (less stringent) restrictions apply. Both solutions, however, share the feature that the aggregation bias is not serious when compared to that in the approach of Coe and Helpman.

A system of equations relating TFP to the different R&D stocks is estimated.[19] On the basis of the discussion so far we can formulate the regression model in a formal way as:

18 To be clear, c_{ji} here indicates again the share of intermediate inputs from sector j in total production of sector i, but now it is the sum of all imports from all foreign sectors j instead of the domestic sector j.

19 To examine the contribution of various factors of production to output, there are two ways to proceed: growth accounting and estimation. We choose TFP as dependent variable – and hence account for growth in capital and labour – and include R&D as independent variables in the regression. This choice might require some elaboration. Assessing also the impact of R&D by growth accounting does not allow to find the excess return we aim to uncover, see note 15. Second, accounting for the changes in capital and labour avoids problems with potential measurement errors and endogeneity in what would otherwise be regressors (capital and labour). Barro (1999, pp. 122-123, 126-127) discusses this issue in more detail.

$$
\begin{aligned}
T_{1t} &= \alpha_1 + \beta_{1,D} D_{1t} + \beta_{1,I} I_{1t} + \beta_{1,F} F_{1t} + \varepsilon_{1t} ,\\
T_{2t} &= \alpha_2 + \beta_{2,D} D_{2t} + \beta_{2,I} I_{2t} + \beta_{2,F} F_{2t} + \varepsilon_{12} ,\\
&\vdots\\
T_{it} &= \alpha_i + \beta_{i,D} D_{it} + \beta_{i,I} I_{it} + \beta_{i,F} F_{it} + \varepsilon_{it} ,
\end{aligned}
\tag{9}
$$

where T, D, I, F stand for log levels of total factor productivity, the direct stock of R&D, the indirect stock of domestic R&D, and the indirect foreign stock of R&D in sector i, respectively.[20] An error term ε is added for every sector i. A constant α_i is added to capture sector specific effects. $\beta_{i,D}$, $\beta_{i,I}$, and $\beta_{i,F}$ are the parameters to be estimated.

So far we emphasised productivity improvements that are passed on to other sectors via intermediate deliveries. This does not imply that we ignore ‘pure’ knowledge spillovers. On the contrary, it is likely that pure knowledge spillovers are also transmitted through the same channel. Intermediate deliveries acting as a mechanism for the propagation of ‘pure’ knowledge spillovers could be important for two reasons. Firstly, a firm can learn from examining the products it buys. And, secondly, a firm can acquire new ideas and knowledge just by communicating with the supplier. It is however not possible, here, to separate rent from knowledge spillovers. Given the discussion in the introduction on the analogous empirical results obtained by IO-based and technology-flow-based weighting matrices, we probably indeed capture both types of spillovers. Therefore, in the remainder we are less specific and use the term spillovers to indicate both types of spillovers.

4 CHARACTERISATION OF SECTORS AND DATA

We examine 11 Dutch industries, of which 4 are service sectors and 7 manufacturing sectors. For these industries we construct direct R&D stocks, indirect domestic R&D stocks using input-output data, and indirect foreign R&D stocks combining input-output data with bilateral trade data. This section briefly discusses our data sources and characterises the eleven sectors.

4.1 *Data Sources*

The data set used in this study consists of three main components: TFP growth rates, R&D investment, and intermediate deliveries.

20 The relation between R_i^f and F_i might need some elaboration. Note that the variable is denoted in logarithms. From the growth rate constructed in equation (8) an index is created, and then logs of this index are taken.

TFP data have been constructed by van der Wiel (1997) on the basis of the growth-accounting approach: growth of TFP equals growth of real value added corrected for growth of quality-adjusted labour services and capital services.

The OECD data set (ANBERD) contains R&D data for manufacturing. For the service sectors in the Netherlands, the ANBERD data are supplemented with R&D data from Statistics Netherlands (CBS). Business enterprise R&D expenditures are available for 15 countries and 26 manufacturing industries.

For weighting Dutch R&D stocks we use input-output data from the CPB Netherlands Bureau for Economic Policy Analysis according to a Dutch sectoral classification (SBI). These IO tables are aggregated from the National Accounts 80x80 IO data from Statistics Netherlands.

For weighting foreign R&D stocks we use bilateral trade data for manufacturing on a sectoral level (STAN Bilateral Trade Database) provided by the OECD. For non-manufacturing industries trade data are not available. Moreover, sectoral import shares cannot be computed for Construction, Communication, and Public Utilities, since data for these services are lacking. We therefore set the foreign R&D stocks for service sectors equal to zero.

4.2 *Industry Characterisation*

A more extensive overview of the data is provided in Appendix A. Here we highlight only some features of the data for the eleven industries. The eleven industries are subdivided into services and manufacturing. The manufacturing sectors are:

- Food, beverages and tobacco (Food);
- Textile, wearing apparel and leather (Textile);
- Wood, furniture and building material (Wood);
- Paper, paper products and printing (Paper);
- Petroleum refineries and miscellaneous products of petroleum and coal (Petroleum);
- Chemical and rubber products (Chemicals);
- Metal industries (Metal).

The latter two industries contain most of the so called ‘high-tech’ industries (see Kusters and Minne (1992)). In the service industries we distinguish:

- Electricity, gas and water (Public Utilities);
- Construction (Construction);
- Communication services, sea, air and other transport and storage (Communication);
- Real estate exploitation, trade, banking, insurance and engineering, commercial, social and health services (Other Services).

During the period 1973-1992 all industries, except Petroleum as a consequence of the oil crises, show positive TFP growth. Table 2 shows for the TFP index and the R&D stocks the level in 1992 relative to the level of 1973. Sectors are ranked by R&D intensity. The sector Communication, the sectors Food, Textile and Paper, and the 'high-tech' industries – Metal and Chemical – experienced TFP growth rates above the unweighted average (14%).

The relatively fast growing sectors are not the largest sectors in the economy. The sector Other Services accounts for over 40% of value added in 1992, whereas the others hardly account for 5% each. Note that a weighted average of openness – see Imports column – would be considerably lower given the large weight of the Other Services sector.[21]

We have also derived the sectoral R&D intensities as measured by the share of R&D expenditures in value added. The highest R&D intensity is found in Chemicals: 12.4% in 1992. Other R&D-intensive industries are Metal with an intensity of almost 5% and Petroleum and Food with almost 2%.

Between 1973 and 1992 the sectoral R&D stocks increased substantially everywhere. In Chemicals, Communication and Other Services they increased with a factor 5 or even 6. It is, however, important to note that even in 1992 the R&D intensity of the last two sectors, Communication and Other Services, is very small (less than 1% of value added). In the other industries the stock at least doubled.

Overall changes in the indirect domestic R&D stock are smaller. Increases vary from only 8% in Petroleum to somewhat more than 50% in Construction. The more moderate development here, compared to 'own' R&D stocks can be traced back to the fact that intermediate use as a share of gross production is usually less than 50% (see the last column in Table 2).[22] The fastest expansion in the indirect domestic R&D stock in Construction is explained by, firstly, the fact that this sector uses a lot of intermediate inputs and therefore potentially benefits a lot from others' R&D. Secondly, the composition of the intermediate inputs is important. For example, Construction uses a large fraction of total inputs from Metal, an industry that had a fivefold increase in its R&D stock. Moreover, supplies from Chemicals to Construction are also above average.

Changes over time in foreign indirect R&D stocks are somewhat more pronounced. R&D-intensive industries – Metal and Chemicals – and Textiles have seen increases in foreign R&D stocks of more than 50%. Not only the import intensity matters for these constructed, sector-specific stocks but also the structure of demand for intermediate (imported) inputs, trade patters and every foreign R&D stock.

21 The shares in total value added do not sum up to unity as Agriculture, Mining and the Public Sector are excluded.

22 Here, intra-industry deliveries are included as well as deliveries by the sectors Mining and Agriculture.

TABLE 2 – SECTORAL STATISTICS IN 1992

	TFP Index	Sectoral R&D (R)	Domestic R&D (R^d)	Foreign R&D (R^f)	Value added*	R&D Intensity**	Imports***	Inter-mediate inputs****
	(1973 = 1.0)				(shares)			
Chemicals	1.54	6.19	1.34	1.64	2.5	12.4	30.9	38.6
Metal	1.33	5.00	1.36	1.54	5.7	4.9	28.0	34.9
Petroleum	0.89	2.00	1.08	1.03	1.3	1.9	51.6	13.6
Food	1.34	3.86	1.29	1.29	2.7	1.8	24.2	54.3
Textile	1.24	3.13	1.41	1.79	0.5	0.8	37.4	29.9
Communication	1.24	5.04	1.31	–	5.6	0.7	13.7	28.0
Wood	1.01	2.33	1.49	1.63	1.0	0.4	27.0	34.2
Public Utilities	1.03	4.09	1.10	–	1.4	0.1	7.0	54.8
Other services	1.08	6.28	1.23	–	41.8	0.1	5.0	29.7
Paper	1.26	3.80	1.35	1.43	1.8	0.1	23.1	36.4
Construction	1.06	2.38	1.53	–	4.4	0.1	12.2	52.5
Average	*1.14*	*4.01*	*1.32*	*1.48*		*2.1*	*23.6*	*37.0*

Sources: R&D data are from ANBERD. The other data are provided by CPB Netherlands Bureau for Economic Policy Analysis.

* % of GDP, percentages do not sum to hundred since Agriculture, Mining and the Public Sector are excluded.

** As a percentage of value added. The numbers differ from Table 1 as the production figures of the Chemicals industry do not include the Petroleum sector.

*** % of the industries' gross production (excluding intra-sectoral deliveries).

**** % of the industries' gross production (including intra-sectoral deliveries).

The data on R&D for services are not as accurate as the data for manufacturing. There are two main difficulties. The first is that the services sectors are rather broad, obscuring that differences in R&D intensity within this sector are significant. For example, Other Services include R&D and computer services as well as retail trade and hotels. The second is that coverage and classification of R&D outlays differ from country to country.[23] Clearly, we cannot avoid these difficulties. However, they provide good reasons to treat the results for services cautiously as well as to run separate regressions for manufacturing and services (section 5.3).

5 EMPIRICAL FINDINGS

The major findings are presented in this section. However, before turning to the results, some econometric issues must be discussed.

5.1 *Econometric Issues*

All data show a clear trend and therefore we seek to estimate equations that are cointegrated. With cointegrated relations the estimated coefficients are consistent.

Unit root tests have been carried out. From this exercise we can infer that most variables are I(1). Im et al. (1997) derive a test for panel data showing whether a variable has a unit root or not. The so called 't-bar' test statistic is the (sectoral) average of the ADF unit root test statistics. All variables have a 't-bar' statistic below the critical value to reject the hypothesis of a unit root based on an ADF regression with two lags. The results are available upon request by authors.

We tested for cointegration of the panel regression equations by applying a pooled *ADF* test statistic to the residuals of the equations.[24] The pooled statistic remains inconclusive about cointegration in some regression equations, but yields evidence in favour of cointegration in most aggregate estimations for a sufficiently large number of lags. Especially, the regression equations at the disaggregated level with the interaction terms seem to be cointegrated. Again, an appendix containing details is available upon request.

Standard errors obtained from estimating equations with non-stationary data are only unbiased under very strong assumptions. This requires cautious interpretation of the reported significance levels.

We have chosen for a two-way fixed effects estimation. That is, we control for sectoral heterogeneity by adding sectoral constants and we add time dummies to

23 Young (1996) discusses the differences among countries in the ANBERD data set in detail.

24 The 't-bar' statistics remained inconclusive about cointegration due to the rather short time series. The reason is that the 't-bar' statistic relies more heavily on the length of the time series than the pooled ADF statistics which also employ the cross-section dimension of the data.

capture time-specific effects. Capacity utilisation rates are included to correct for the business cycle.

Results for the case where parameters are restricted to be equal across sectors are first presented and discussed. Next the cross-product of sectoral and foreign R&D is included in the regression model to test the hypothesis that sectoral domestic R&D facilitates the adoption of foreign technologies. Finally, the group of eleven sectors is disaggregated into manufacturing and services to allow for differences between these two broadly defined sectors.

5.2 *The Aggregate Model*

The first regressions we present are based on equation (9) with all parameters restricted to be the same for each sector. Table 3 presents the estimates.

First, we include the 'own' R&D stocks only. We find a significant elasticity for own R&D. Inclusion of the indirect R&D stock in column (II) does not alter this finding. Column (II) gives support for the presence of domestic R&D spillovers. However, the indirect effect is very high and it might partly pick up the (excluded) effect of foreign R&D.

Column (III) is the basic regression result that will be used throughout this paper. The elasticity of own R&D equals 37%. This elasticity is also the elastic-

TABLE 3 – OLS ESTIMATION RESULTS AGGREGATE MODEL. DEPENDENT VARIABLE IS LN(TFP)*

Variable	(I) Direct effect	(II) Direct + indirect effect	(III) Base run	(IV) Return
D	0.309***	0.369***	0.363***	0.220***
	(0.048)	(0.037)	(0.032)	(0.039)
I	–	1.80***	0.926***	1.10***
	–	(0.15)	(0.18)	(0.22)
F	–	–	0.649***	0.334***
	–	–	(0.088)	(0.121)
R^2	0.54	0.53	0.65	0.55
N	220	220	220	220
F (sector constants = 0)	10.1***	23.9***	13.0***	21.3***
F (time dummies = 0)	1.35	8.36***	9.51***	3.26***
F (all coeff. = 0)	7.81***	19.6***	26.4***	16.1***

* Sample period is 1973–1992, 11 sectors. Sector-specific constants, time dummies and capacity utilisation rates are included. Standard errors are given in parentheses under the estimates. *, **, and *** denote statistical significance at the 10% level, the 5% level, and the 1% level, respectively.

ity of output with respect to R&D. Including the foreign R&D stock not only reduces the estimated indirect effect of domestic R&D, but also demonstrates that foreign R&D spillovers are important. The domestic (I) and foreign (F) spillover terms are positive and significant. The Dutch sectors clearly benefit from R&D activities at home and abroad. It is reminded that the foreign R&D stock is relevant only for manufacturing sectors.

The results are robust with respect to changes in the depreciation rates. We have analysed the effects on our estimates of reducing the depreciation rate of R&D investments from 15% to 7.5%: the estimated coefficients change only little. We also estimated the base run with TFP figures based on gross production as explanatory variables. The coefficients are then reduced but the qualitative results of the base run remain unaffected.

Impact of Spillovers

To compare the direct effects and the indirect effects of R&D, we compute output elasticities, that is: an increase in sectoral TFP and output as a result of a 100% increase in all sectoral R&D stocks. The coefficients for I and F must be corrected for the weighting schemes.[25] Table 4 shows the calculated elasticities. We find the total output elasticity to be 14.7%.[26] Since the direct effect of R&D is characterised by an output elasticity of 37%, the indirect effect of domestic R&D is substantial. The indirect effect is about half as strong as the direct effect.

The results in Table 4 and Table B.1 in Appendix B partly reflect the structure of the economy. The sector Other Services has a large impact on productivity in the other sectors, simply because this sector is an important supplier of other sector's intermediate inputs.[27]

To gauge the effect of foreign R&D a similar procedure must be applied.[28] We find the elasticity of total output with respect to foreign R&D to be somewhat less than 3% (Table B.2 in Appendix B shows from which countries and industries this effect originates). This result points to the conclusion that domestic spillovers are more important than international spillovers. The estimated ef-

25 The procedure for the indirect effect of domestic R&D on total output runs at follows. Firstly, multiply all weights with the coefficient ß to get a matrix with cross elasticities. These are the elasticities of sector i's productivity with respect to sector j's R&D stock. Table B.1 in Appendix B gives these elasticities. Secondly, sum over i, weighting with the share of each sector in total production to find the indirect effect of R&D in sector j on total production in the Netherlands.

26 The sum of shares is equal to one; this assumes that the indirect effect is on average the same for the omitted sectors: Agriculture, Mining and the Public Sector.

27 The counterpart of this observation is that sectoral productivity is relatively sensitive to R&D elsewhere if a sector intensively uses intermediate goods, see for example Construction (BO) and Wood (HB) in Table B.1 in Appendix B.

28 First, multiply the weights with the estimated parameter and sum the resulting elasticities over countries to find the total effect on sectoral TFP of an increase in the sector-specific foreign R&D stock (see Table B.2). Then, weight all sectoral elasticities with output shares to find the total output elasticity.

TABLE 4 – ELASTICITIES OF OVERALL TFP WITH RESPECT TO R&D IN VARIOUS SECTORS (%)*

	Indirect effect	Share in value added
Chemicals	0.71	3.6
Metal	1.51	8.5
Petroleum	0.47	0.6
Food	0.84	4.0
Textile	0.13	0.7
Communication	2.71	9.2
Wood	0.66	1.5
Public Utilities	0.90	2.1
Other Services	4.32	60.6
Paper	1.28	2.7
Construction	1.19	6.5
Total elasticity	14.7	100

* The 1992 weights are used to calculate the elasticities.

fect of foreign R&D does not seem to vindicate the idea that the Netherlands is too small to affect the pace of technical change and that the Dutch potential to grow depends entirely on technical developments abroad.

This result, however, needs some qualification. That the output elasticity of foreign R&D spillovers in only 2.8% is partly a result of the model specification. The regression equations for manufacturing sectors include a measure for foreign R&D activities, but the equation for the other sectors does not. The last group, non-tradeable services, accounts for at least two-thirds of total production. One could argue that effect of foreign R&D is underestimated, since foreign R&D does not feature in some equations.

An alternative perspective is then to consider only the effect of foreign R&D on manufacturing output. Then, we find that the weighted average of output elasticities for manufacturing sectors in considerably higher: 12.9% (the number reported in Table 5). Nevertheless, even for manufacturing it is true that domestic R&D is at least as important as foreign R&D. This conclusion is likely to hold *a fortiori* for non-tradeable services and thus for the total economy.

It is illustrative to look at the spillovers from different countries separately, as we do in Table 5. Table 5 reports the elasticity of TFP in manufacturing with respect to R&D in country *k*. It should not come as a surprise that the largest trading partners of the Netherlands have the highest output elasticities. The foreign country R&D elasticities largely reflect the trade pattern, since intermediate deliveries form the basis of the weighting scheme. Germany is the most dominant: the elasticity of manufacturing output with respect to German R&D is 5.3%.

TABLE 5 – ELASTICITIES OF TFP IN DUTCH MANUFACTURING TO R&D IN VARIOUS COUNTRIES (%)

	Elasticity
Australia	0.01
Canada	0.11
Denmark	0.26
Spain	0.26
Finland	0.31
France	1.57
Germany	5.34
Iraly	0.75
Japan	0.61
Norway	0.14
Sweden	0.54
U.K.	1.68
U.S.A.	0.35
Weighted elasticity	12.9

The analogous cross-industry effects are shown in Table 6. The most important foreign sector for the Dutch economy is Metal, followed by Chemicals. A 100% increase in R&D in Metal in the rest of the OECD leads to a 5.4% increase of TFP in the Dutch economy.

Finally, in column (IV) of Table 3 we present an estimation that approximates the rates of return to R&D investment. These return estimates are obtained by pre-multiplying the direct stocks with the average sectoral R&D intensity over the time period. We are mainly interested in the 'own' sector rate of return for which we find a rate of 22%. This number is to be interpreted as the excess

TABLE 6 – ELASTICITIES OF MANUFACTURING TFP TO R&D IN VARIOUS FOREIGN SECTORS (%)

	Elasticity
Chemicals	3.34
Wood	0.85
Metal	5.39
Petroleum	0.29
Paper	1.48
Textile	0.49
Food	1.08
Weighted elasticity	12.9

return that R&D investment generates for other agents within the same industry. Given that the elasticity of domestic spillovers is 1/2 of the 'own' elasticity, we may infer that the social rate of return is at least one-and-a-half times the private return. Therefore, a lower bound of the social (excess) return to R&D of approximately 30% would result on the basis of our estimated return to R&D. In the remainder of the discussion we concentrate again on the estimated elasticities.

How do the estimated elasticities compare to the findings in the literature? Nadiri (1993) reports elasticities at the industry level of 6 to 42%. The elasticity for 'own' sectoral R&D is at the upper end of this range. Keller's (1997) estimates are roughly in the same order of magnitude as ours.[29] In a comparable set-up, he finds, for the direct effect, a coefficient of 21%. Verspagen (1997) on the other hand finds an elasticity of 10%.

The finding that domestic spillovers are important – we find an elasticity of 15% – confirms results found elsewhere, see e.g. Keller (1997) and Branstetter (1996). Verspagen (1997) finds for the domestic spillover elasticities between 2% and 9%. Nadiri's (1993) overview reports findings ranging from 10% to 26%.

One of the main questions in the introduction is relative importance of domestic *versus* foreign spillovers. So far domestic spillovers seem to dominate foreign spillovers. Coe and Helpman find an elasticity of TFP to foreign R&D of 6-9%. This is lower than our finding of 12.9%. However, this comparison is not entirely correct. First, the construction of the data differs, so that results are bound to differ as well.[30] Second, the elasticities reported by Coe and Helpman apply to the total business sector, whereas our finding of 12.9% applies to manufacturing only. Third, Coe and Helpman experiment with different regression equations. In their preferred equation they allow the level of imports to be reflected 'properly' (p. 863) in the explanatory variables; that is, they pre-multiply the spillover construct by the import intensity as measure for openness. In that case the elasticity of foreign R&D for the Netherlands becomes slightly higher than 15%. That implies that our finding of an elasticity of 12.9% for manufacturing is in line with the findings for the total business sector by Coe and Helpman. It is only our finding that domestic spillovers are at least as important as foreign spillovers, that downplays the role of foreign R&D, also for a small open economy.

Absorptive R&D

In an extension of the model we test whether domestic R&D improves the capacity to absorb ideas and technologies (Cohen and Levinthal (1989)). Introduc-

29 In Keller (1997) a multi-country, multi-sector model is estimated on the same OECD data for R&D. The Netherlands, however, is not included. He constructs his own TFP index.

30 First, we weight growth rates of R&D stocks. The foreign R&D stock's growth rate is constructed as, $\sum (m_k/y)\,(\Delta R_k/R_k)$ where m_k is the flow of imports from country k to the Netherlands and R denotes a R&D stock. For expository purposes the sectoral dimension is ignored. From this growth rate an index is made where after logs are taken. The comparable Coe and Helpman equation would use $\log \sum s_k R_k$, where s_k denotes the import shares of the Netherlands which sum to unity.

ing an interaction term of R&D within a sector and R&D outside this sector is one way of doing this. Since the idea is concerned with pure knowledge spillovers, we take the unweighted sum of stocks as a measure for indirect domestic and foreign R&D. This has the advantage that we are now able to construct a cross-term for the service sectors as well. Table 7 presents the estimation results.

In the column labelled (IV) we have included the interaction between sectoral R&D and total domestic R&D ($D*I$). The estimated coefficient for the interaction term is significant and positive. In column (V) we included the interaction between sectoral and foreign R&D ($D*F$). The estimate for the cross-product is positive and significantly different from zero.

R&D investments within the Netherlands seem complementary. Moreover, R&D investments in- and outside the Netherlands are complementary too. The return on domestic R&D increases with foreign R&D efforts. Note that the size and significance of the coefficient for own R&D drop.

Summary of Findings

The elasticity of TFP with respect to own R&D is about 37% in all estimations without interaction effects. The indirect effect of domestic R&D is important; the

TABLE 7 – OLS ESTIMATION RESULTS AGGREGATE MODEL. DEPENDENT VARIABLE IS LN(TFP)*

Variable	(III) Base run	(IV) Interaction with domestic R&D	(V) Interaction with foreign R&D
D	0.363***	0.140	0.156*
	(0.032)	(0.089)	(0.090)
I	0.926***	1.05***	1.04***
	(0.18)	(0.18)	(0.18)
F	0.649***	0.623***	0.626***
	(0.088)	(0.087)	(0.088)
$D*I$	–	0.0251***	–
	–	(0.0095)	–
$D*F$	–	–	0.00467**
	–	–	(0.0019)
R^2	0.65	0.62	0.76
N	220	220	220
F (sector constants = 0)	13.0***	14.1***	13.9***
F (time dummies = 0)	9.51***	10.6***	10.44***
F (all coeff. = 0)	26.3***	26.4***	26.3***

* Sample period is 1973–1992, 11 sectors. Sector-specific constants, time dummies and capacity utilisation rates are included. Standard errors are given in parentheses under the estimates. *, **, and *** denote statistical significance at the 10% level, the 5% level, and the 1% level, respectively.

elasticity is 15%. The effect of foreign R&D is significant, but seems to be less important than domestic R&D because the aggregate TFP elasticity is only 2.8%. Domestic spillovers dominate foreign spillovers, largely reflecting that domestic trade is more intense than international trade. We also find evidence for the suggestion that domestic R&D accelerates the adoption of both other domestic as well as foreign ideas and technologies.

5.3 *A Disaggregated Model*

A next step is to examine the role of domestic and foreign R&D at a more disaggregated level. The constraint that all parameters are equal for each sector, might be too restrictive. Furthermore, the data on R&D in services are not as accurate as the data for manufacturing (see the end of section 4.2). The sectors are therefore divided into two subsets, namely manufacturing and services. Table 8 presents the estimation results.

In column (I) we include D only. Subscripts m and s stand for manufacturing and services, respectively. Own R&D is more potent in services (D_s) than in manufacturing (D_m). Including the domestic R&D spillover stocks (I_m and I_s), however, reverses this result again. The estimates for the direct effect of R&D are now lower, and insignificant in services. The effect of the domestic R&D stock for manufacturing is again large. Foreign R&D (F_m), column (III) is only relevant for the manufacturing sectors – the foreign variable F_m is identical with F in the table with aggregate results. The coefficient for foreign R&D equals that derived from the aggregate estimations. The effects of indirect R&D are lower for manufacturing than for services.

Inside and Outside R&D
Column (IV) refines are analysis of foreign R&D spillovers in manufacturing. Knowledge spillovers are perhaps more important among firms in a similar branch than among firms belonging to different sectors and producing different goods. To see whether the data support this idea we separate R&D investment by similar sectors abroad from R&D investment in other foreign sectors. Consider for example the sector Chemicals. This sector has an 'own' foreign R&D stock – R&D performed by similar sectors abroad weighted by using data for the total import of chemicals and the bilateral trade pattern in this sector. This implies that the industry's non-diagonal elements of the imported inputs matrix are set to zero. Furthermore, Chemicals has an 'other', foreign R&D stock – R&D performed by different sectors abroad weighted by data for all non-chemical imported imputs by the Chemicals industry. To construct this stock, the diagonal elements of the imported inputs matrix are set to zero.

Surprisingly, the coefficient for 'own' sector foreign R&D (DF in column IV) is about three times lower for than the coefficient for 'other' sector foreign R&D (IF). The coefficient for 'own' sector foreign R&D is comparable to Keller's

TABLE 8 – OLS ESTIMATION RESULTS MANUFACTURING VERSUS SERVICES. DEPENDENT VARIABLE IS LN(TFP)*

Variable	(I) Direct only	(II) Direct + indirect effects	(III) Base run	(IV) Separate *DF* and *IF*
D_m	0.331***	0.387***	0.366***	0.423***
	(0.049)	(0.035)	(0.032)	(0.035)
I_m	–	1.15***	0.799***	−0.00564
	–	(0.15)	(0.18)	(0.41)
F_m	–	–	0.632***	–
	–	–	(0.10)	–
DF_m	–	–	–	0.846***
	–	–	–	(0.20)
IF_m	–	–	–	2.14***
	–	–	–	(0.62)
D_s	0.407***	0.155*	0.111	0.216**
	(0.065)	(0.087)	(0.080)	(0.092)
I_s	–	3.03***	3.01***	2.96***
	–	(0.29)	(0.27)	(0.26)
R^2	0.58	0.61	0.68	0.74
N	220	220	220	220
F (sector constants = 0)	8.4***	17.3***	10.1***	9.9***
F (time dummies = 0)	1.6**	8.4***	9.3***	6.9***
F (all coeff. = 0)	7.8***	23.0***	28.3***	27.9***

* Sample period is 1973–1992, 11 sectors. Sector-specific constants, time dummies and capacity utilisation rates are included. Standard errors are given in parentheses under the estimates. *, **, and *** denote statistical significance at the 10% level, the 5% level, and the 1% level, respectively.

(1997). If we keep in mind that the share of ‘own’ sector imports is about three times as high as ‘other’ sector imports, the total impact of both R&D activities is approximately the same.

Absorptive R&D

Analogous to the estimations at the aggregate level we include interaction terms for R&D inside and outside a sector, where ‘outside’ may refer to R&D in the Netherlands or to R&D in foreign countries. Table 9 presents the effects for absorptive R&D.

The interaction term for sectoral R&D and other domestic R&D, in column (IV), is weakly significant and positive for services and manufacturing. With regard to the interaction term for ‘own’ and foreign R&D, only for manufacturing the coefficient for the cross-term is positive and significant.

TABLE 9 – OLS ESTIMATION RESULTS MANUFACTURING VERSUS SERVICES. DEPENDENT VARIABLE IS LN(TFP)*

Variable	(III) Base run	(IV) Interaction with domestic R&D	(V) Interaction with foreign R&D
D_m	0.366***	0.194**	0.201**
	(0.032)	(0.091)	(0.091)
I_m	0.799***	0.948***	0.945***
	(0.18)	(0.20)	(0.20)
F_m	0.632***	0.600***	0.598***
	(0.10)	(0.10)	(0.10)
$D_m{*}I_m$	–	0.0198**	–
	–	(0.0099)	–
$D_m{*}F_m$	–	–	0.00383*
	–	–	(0.0020)
D_s	0.111	−0.0367	−0.039
	(0.080)	(0.15)	(0.15)
I_s	3.01***	2.94***	2.96***
	(0.27)	(0.27)	(0.27)
$D_s{*}I_s$	–	0.651***	–
	–	(0.069)	–
$D_s{*}F_s$	–	–	0.00446
	–	–	(0.0030)
R^2	0.68	0.65	0.65
N	220	220	220
F (sector constants = 0)	10.1***	10.1***	10.0***
F (time dummies = 0)	9.3***	9.5***	9.4***
F (all coeff. = 0)	28.3***	26.6***	26.6***

* Sample period is 1973–1992, 11 sectors. Sector-specific constants, time dummies and capacity utilisation rates are included. Standard errors are given in parentheses under the estimates. *, **, and *** denote statistical significance at the 10% level, the 5% level, and the 1% level, respectively.

Summary of Findings

Table 8 confirms the results of the base run. An important difference is that the indirect effect of domestic R&D is lower for manufacturing than for services. We find again support in the disaggregated estimations for the view that R&D helps to absorb foreign knowledge. The effect of 'own' R&D on absorption of domestic and foreign knowledge is important for manufacturing. For services, there does not seem to be a stable direct effect of R&D but there is a strong effect of 'own' R&D on the adoption of domestic knowledge spillovers.

6 CONCLUSIONS

Is domestic or foreign R&D the driving force behind productivity growth? That is the central question in this paper. If spillovers are predominantly international, policy might optimally be aimed at assimilating foreign technologies rather than at stimulating domestic investment in R&D. If spillovers, however, are predominantly (intra)national, the Netherlands should take the advice from Jones and Williams (1988) seriously. In view of the large social returns associated with R&D, they argue that the United States should quadruple R&D efforts. Our evidence supports both ideas. Both domestic R&D as well as foreign R&D have a positive impact on productivity growth in the Netherlands.

The elasticity of total factor productivity with respect to R&D is 37% for R&D by a sector, 15% for R&D by other Dutch sectors and almost 3% for R&D by foreign sectors. Our findings also suggest that more R&D speeds up adoption of foreign technologies.

A more disaggregated analysis learns that for manufacturing the results are confirmed. For services, ‘own’ R&D seems largely effective on the adoption of domestic knowledge spillovers, not directly.

In sum: provided that implementation problems could be overcome, a policy to stimulate R&D is desirable for three reasons. First, R&D within manufacturing industries generates an excess return. Second, domestic spillovers are important for the Netherlands. Third, R&D in both services and manufacturing industries enhance the absorption of foreign R&D spillovers. In the introduction, we considered a ‘wait for things to happen’ policy, that is, to let foreign countries do R&D and benefit from their results as a small country. Such a policy of waiting is not supported by our analysis.

APPENDIX A

DATA

Van der Wiel (1997) constructed the TFP figures. The Jorgenson growth accounting approach is used: TFP growth is constructed as value added corrected for weighted labour services and capital services. The weights are average (Divisia) nominal income shares. Labour services are (contract) hours worked. The labour services are adjusted for quality by weighting changes in the composition of characteristics of workers. The characteristics of workers are related to quality by estimating an equation with wages (as a proxy for quality) as dependent variable on worker characteristics.

The R&D data are from the OECD (ANBERD), supplemented with data from Netherlands Statistics (CBS) for the Communication industry in the Netherlands. The maximum time period covered is 1973 to 1995 (we use: 1973–1992). The business enterprise R&D expenditures are available for 15 countries and 26 manufacturing industries and five service sector industries. The CBS data have been downloaded from (http://statline.cbs.nl/witch/etc/scratch/531924634:6376r_d00.html) on 25-6-97. The Statistics Netherlands data for 1988 have been interpolated as huge outliers were found for some industries. The Statistics Netherlands (CBS) data – available as expenditure in guilders – have been transformed in constant dollars using the GDP PPP indicator from STAN bilateral trade data. The CBS data, for which ANBERD data are available, turn out to correspond very well using the imperfect PPP measure.

The R&D stocks (*R*) are constructed as a perpetual inventory of the flow of R&D investments (*RD*). The first data point constructed as,

$$R_{t=0} = \frac{RD_{t=0}}{\Delta + g}, \tag{i}$$

where g is the average growth rate of the R&D investments and Δ is the depreciation rate. The subsequent stocks are constructed as follows,

$$R_t = \sum_{t=1}^{t=\tau} RD_t - \Delta R_{t-1}. \tag{ii}$$

Nadiri and Prucha (1993) estimate the depreciation rate to be 12%. Pakes and Schankerman (1984) find a rate of 25%. The depreciation rate we apply equals 15%, and is the same as in Coe and Helpman (1995) appendix B, Branstetter (1996) and Los and Verspagen (1996).

The Dutch input-output data are from the CPB Netherlands Bureau for Economic Policy Analysis in the SBI (used for the Athena model). The data are without structural changes in definitions. The IO tables are aggregated from the National Accounts 80x80 IO data from Statistics Netherlands (CBS).

Capacity utilisation rates are from the CPB Netherlands Bureau for Economic Policy Analysis in the SBI (used for the Athena model). The other services sector is proxied by the construction sector.

Bilateral trade data for manufacturing on a sectoral level from STAN Bilateral Trade Database (OECD) are available for Australia, Canada, Denmark, Finland, France, Federal Republic of Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States. The available length of the time series is 1970 to 1992 (we use: 1973–1992). Data for Ireland, New Zealand and Portugal are not used.

To aggregate the ANBERD data, STAN Bilateral Trade Database, CPB IO data, a concordance is used, which is available upon request from the authors.

APPENDIX B

ESTIMATED ELASTICITIES

TABLE B.1 – ELASTICITIES OF TFP IN SECTOR *i* TO R&D IN SECTOR *j* (%)

		BO	CR	CT	DT	HB	ME	ON	OR	PG	TK	VG	Elas-ticity
Construction	(BO)		0.56	3.01	1.32	1.01	0.49	0.18	0.20	0.56	0.33	0.23	1.19
Chemicals	(CR)	1.32		0.09	0.59	2.28	1.51	0.32	0.18	1.11	3.71	0.84	0.71
Communication	(CT)	0.50	0.60		4.15	0.54	0.65	0.63	0.33	1.69	0.51	0.28	2.71
Other Services	(DT)	10.94	11.83	10.20		15.65	13.13	3.47	4.48	10.85	11.24	10.64	4.32
Wood	(HB)	7.12	0.36	0.06	0.21		0.30		0.01	0.20		0.37	0.66
Metal	(ME)	6.05	1.32	1.71	1.29	1.46		1.96	0.53	0.80	1.50	0.81	1.51
Public Utilities	(ON)	0.20	1.73	0.77	0.90	1.94	1.29		0.31	0.84	1.12	0.96	0.90
Petroleum	(OR)	0.47	2.51	1.96	0.20	0.43	0.33	0.31		0.14	0.20	0.12	0.47
Paper	(PG)	0.12	1.26	0.64	1.67	0.82	0.57	0.15	0.15		0.78	2.07	1.28
Textile	(TK)	0.02	0.08	0.05	0.17	0.24	0.08		0.01	0.05		0.01	0.13
Food	(VG)	0.03	0.55	0.20	1.30		0.01			0.21	0.74		0.84
Σ		26.76	20.81	18.69	11.80	24.35	18.36	7.02	6.21	16.43	20.14	16.32	
Share in Y*		6.54	3.61	9.23	60.57	1.46	8.54	2.11	0.63	2.66	0.68	3.98	100.00
Weighted elasticity		1.75	0.75	1.72	7.15	0.35	1.57	0.15	0.04	0.44	0.14	0.65	14.71

* Shares sum to one.

TABLE B.2 – ELASTICITIES OF TFP IN SECTOR *i* TO R&D IN COUNTRY *k**

	CR	HB	ME	OR	PG	TK	VG	Elasticity
Australia	0.03	0.01	0.01	0.00	0.00	0.02	0.02	0.01
Canada	0.11	0.12	0.12	0.01	0.19	0.07	0.06	0.11
Denmark	0.36	0.35	0.25	0.03	0.15	0.48	0.23	0.26
Spain	0.36	0.26	0.28	0.03	0.15	0.35	0.21	0.26
Finland	0.25	0.50	0.13	0.03	1.29	0.12	0.10	0.31
France	2.29	1.51	1.53	0.09	1.29	2.11	1.34	1.57
Germany	6.09	6.67	5.85	0.28	4.81	9.79	3.47	5.34
Italy	0.81	1.24	0.78	0.06	0.43	2.66	0.46	0.75
Japan	0.62	0.37	1.05	0.02	0.18	0.44	0.12	0.61
Norway	0.20	0.16	0.13	0.03	0.27	0.07	0.04	0.14
Sweden	0.43	0.75	0.54	0.03	1.32	0.30	0.14	0.54
U.K.	2.55	1.27	1.91	0.21	1.32	2.23	0.94	1.68
U.S.A.	1.81	0.95	1.70	0.08	0.99	1.19	0.78	1.35
Σ	15.91	14.18	14.28	0.91	12.38	19.80	7.91	
Share in manufacturing**	16.80	6.80	39.60	2.90	12.30	3.10	18.50	100.00
Weighted elasticity manufacturing	2.67	0.96	5.66	0.03	1.52	0.61	1.46	12.92
Share in total value added	3.60	1.50	8.50	0.60	2.70	0.70	4.00	12.92
Weighted elasticity	0.57	0.21	0.21	0.01	0.33	0.14	0.32	2.79

* BO = Construction, CR = chemicals, CT = Communication, DT = Other services, HB = Wood, ME = Metal, ON = Public utility, OR = Petroleum, PG = Paper, TK = Textile

** Shares sum to one.

TABLE B.3 – ELASTICITIES OF TFP IN SECTOR *i* TO R&D IN SECTOR *j* (GLOBAL)

		CR	HB	ME	OR	PG	TK	VG	Elasticity
Chemicals	(CR)	12.70	2.39	1.25	0.12	1.57	6.18	0.85	3.34
Wood	(HB)	0.21	8.91	0.43	0.01	0.09	0.00	0.17	0.85
Metal	(ME)	0.73	1.95	12.37	0.23	0.49	1.06	0.73	5.39
Petroleum	(OR)	1.52	0.01	0.05	0.54	0.02	0.00	0.01	0.29
Paper	(PG)	0.47	0.13	0.10	0.01	10.10	0.14	0.55	1.48
Textile	(TK)	0.08	0.80	0.08	0.01	0.06	12.25	0.03	0.49
Food	(VG)	0.21	0.00	0.00	0.00	0.05	0.18	5.57	1.08
Σ		15.92	14.18	14.28	0.91	12.38	19.80	7.91	
Share*		16.80	6.80	39.60	2.90	12.30	3.10	18.50	
Share in Y		2.67	0.96	5.66	0.03	1.52	0.61	1.46	
Weighted elasticity		3.60	1.50	8.50	0.60	2.70	0.70	4.00	12.92
		0.57	0.21	1.21	0.01	0.33	0.14	0.32	2.79

* Shares sum to one

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