R&D Internationalization, R&D Collaboration and Public Knowledge Institutions in Small Economies: Evidence from Finland and the Netherlands

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Abstract

This paper investigates domestic and foreign innovating firms' determinants of R&D collaboration with domestic universities and public knowledge institutes in Finland and the Netherlands. We put particular emphasis on the impact of incoming academic spillovers on the probability to co-operate with these public R&D institutes.

Based on data from Community Innovation Surveys we find that foreign firms in the Netherlands are less likely to co-operate with domestic public knowledge institutions than domestic firms, while in Finland no significant difference can be detected. Another result is that incoming knowledge spillovers are an important determinant for R&D collaboration with domestic public knowledge institutions in both countries. In case of foreign firms in Finland, incoming knowledge spillovers affect the probability to co-operate with public knowledge institutions more positively as compared with domestic firms. For the Netherlands no substantial difference could be found in this respect. Further, innovating firms in Finland that require academic or basic knowledge do not co-operate significantly more with public knowledge institutions than those that need applied knowledge. At the same time they are willing to share knowledge with public R&D partners. In the Netherlands innovating firms that require relatively more basic than applied knowledge, increase the probability of co-operation with Dutch universities and public knowledge institutions but there is reluctance to share proprietary knowledge with public R&D partners. For both countries no significant difference between foreign and domestic firms with regard to academic knowledge requirements could be found. This raises the issue whether Finnish innovation policies with a strong focus on R&D co-operation provide incentives for strategic behaviour by domestic public partners to put more emphasis on applied research.

1. Introduction

Research and Development (R&D) collaboration is a means to increase the impact of R&D on economic growth through enhanced R&D productivity and technological diffusion. More specifically, R&D collaboration between innovating firms and public R&D institutions, i.e. universities and/or public R&D institutes, is a channel through which academic R&D spillovers can be internalized by innovating firms. Innovation policies aimed at stimulating R&D co-operation between innovating (foreign) firms and domestic universities and public knowledge institutes, are important instruments to encourage academic spillovers to innovating firms and hence contribute to their innovative contribution to the domestic economy.

An increasing number of studies deal with R&D collaboration between firms and public knowledge institutions. Most of these studies focus on the large economy of the United States (e.g. Mansfield, 1980, 1991, 1995; Hall *et.al*, 2003). Less attention has been paid to R&D co-operation between innovating firms and public knowledge institutions in small countries. This is an important issue as in small countries a larger part of domestic production and R&D is done by foreign firms than in large nations. Increased competition and the increasing complexity of technologies stimulate innovating Multinational Enterprises (MNEs) to relocate R&D investments such as to access knowledge in foreign public knowledge institutions and research talent. This encourages them to co-operate with other firms and public knowledge institutions both domestically and abroad (Archibugi and Iammarino, 1999; World Investment Report 2005).

As MNEs are much more footloose than domestic firms (Blomström and Kokko, 2003), it is more pressing for small countries to be an attractive location for

innovating foreign firms as a means to increase national innovative capacity (Furman, *et.al*, 2002).

This study investigates the determinants of R&D collaboration of innovating firms with public knowledge institutions in Finland and the Netherlands. We distinguish between foreign and domestic innovating firms and put particular emphasis on incoming academic knowledge spillovers that are expected to lead to higher rates of return than non-academic spillovers (Adams, 1990). Further, we relate the results to different innovation policies between these two countries.

The choice of a comparison between Finland and the Netherlands is motivated by their small size and differences in innovation policies.[1] In Finland, more weight is attached to networking and integrating firms and universities into a national innovation system than in the Netherlands. Consequently, Finnish policy-induced collaboration can be expected to link innovating firms to the domestic public knowledge institutional structure, i.e. universities (including academic hospitals) and public R&D institutes, more effectively than Dutch innovation policies. In other words, innovating firms in Finland will – ceteris paribus – more often co-operate with domestic knowledge institutions and hence benefit more from academic knowledge spillovers than in the Netherlands (Hjerppe and Kiander, 2004; Nieminen and Kaukonen, 2001).

In order for these innovation policies to be effective it is important to investigate whether (academic) knowledge spillovers is an important motive of innovating firms to co-operate with universities and public knowledge institutes. When innovating firms do not consider academic knowledge spillovers as an important incentive to co-

[1] Although the Netherlands has twice as many inhabitants as Finland, it is still considered a small country in the European Union.

operate with public knowledge institution, the theoretically expected higher benefits of academic spillovers for economic growth might not materialize.

We first investigate whether foreign innovating firms are less or more involved in R&D co-operation with domestic universities and public R&D institutes than innovating domestic firms. As foreign firms are more mobile or footloose than domestic firms it can be expected that foreign firms are less connected to the domestic public knowledge institutions than domestic firms. Then, we examine whether incoming knowledge spillovers and the firms' needs for academic or basic research affect the probability to collaborate with domestic public knowledge institutions and particularly, whether the effects are different when distinguishing between foreign and domestic firms. Incoming knowledge spillovers are measured by the use of publicly available information sources in the firm's innovation process. The academic character of spillovers is measured by the need of basic relative to applied research.

The contribution of this paper is twofold. First, it investigates differences between domestic and foreign firms' intensities to collaborate with public knowledge institutions with a special emphasis on academic knowledge spillovers. Second, it compares the results of two small open economies with different innovation policies by using large-scale cross-industry data.

Our results are based on Dutch and Finnish Community Innovation Survey (CIS) data for the second half of the 1990s. They show that in Finland no difference exists between foreign and domestic firms in the probability to co-operate in their research activities with domestic public knowledge institutions. In the Netherlands innovating foreign firms' probability to co-operate with domestic public knowledge institutions is lower as compared with domestic innovating firms. Incoming knowledge spillovers are an important determinant for R&D collaboration of innovating firms with

domestic public knowledge institutions in both countries. However, in case of foreign firms incoming knowledge spillovers in Finland affects the probability to co-operate with public knowledge institutions more as compared with domestic firms. For the Netherlands no substantial difference between foreign and domestic spillovers could be found. Further, innovating firms in Finland that require academic or basic knowledge do not co-operate significantly more with public knowledge institutions than those that need applied knowledge. However, they are willing to share their own knowledge with public R&D partners. In the Netherlands innovating firms that require relatively more basic than applied knowledge, have a higher probability of co-operation with Dutch universities and public knowledge institutions but there is reluctance to share ideas originally developed by the innovative firms, with public R&D partners. For both countries no significant difference between foreign and domestic firms with regard to academic knowledge requirements could be found.

The paper is organized in seven sections. In the next section, the motives of R&D co-operation between firms and public knowledge institutions for both partners are summarized. Hypotheses explaining R&D co-operation with public partners are formulated in section 3. In section 4 the model and its operationalisation is described. Section 5 describes some macro-data on Multinational Enterprises (MNEs) and R&D investments, as well as the Community Innovation Survey (CIS) micro-data that are used for the econometric estimates shown in section 6. The final section reports the conclusions.

2. Theoretical background and empirical research on private-public research co-operation

2.1 Motives of innovating firms

Since the 1980s, an increasing variety of collaborative arrangements between innovating firms have emerged. More rapid and complex technologies together with easier dissemination of information encourage innovating firms to co-operate on R&D with other firms or R&D institutes (Baumol, 2002). Other motives include cost sharing, uncertainties inherent in developing new technologies, and access to tacit knowledge (Hagedoorn, 1993). The growing literature on various types of R&D collaboration schemes has recently shifted its focus to motives in R&D partner selection, such as e.g. alliances among private or public R&D organizations (Leiponen, 2002).

R&D co-operation with public knowledge institutions offer innovating firms the complementary characteristics of public knowledge institutions' skills and knowledge (Bower, 1993; Santoro and Gopalakrishnan, 2000). Especially universities offer firms access to fundamental or basic research, as well as to a pool of potential recruits. Meanwhile, firms have practical knowledge of market opportunities for new products, and the incentives to commercialise research results into innovations.

The active search for new product ideas and new forms of organization are an integral part of innovating firms' strategies to gain or sustain a competitive advantage (Eisenhardt and Martin, 2000). Laursen and Salter (2004) find that firms that use many external sources of knowledge in their innovations also tend to use more knowledge drawn from universities. They conclude that the more "open" the search strategy of the firm, the more university research is used intensively.

2.2. Motives of policy-makers

In the last twenty-five years, the linear innovation model, involving the idea that knowledge originates in universities and automatically spills over to firms, has lost importance (Cohen *et.al*, 2002). Since the 1980s, several studies have pointed out that innovation processes are characterized by an interactive relationship between public and private research (Feller 1990; Jaffe, 1989; Mansfield, 1991, 1998; Narin et.al, 1997; von Hippel, 1988). This interaction between firms and publicly funded knowledge institutions is considered an important determinant of innovation, and therefore of economic growth and national competitiveness (OECD, 2002). Universities and public R&D institutes generate substantial R&D spillovers and contribute thus to the social returns to innovation. Basic R&D is estimated to enjoy high rates of return (Mansfield, 1980; Adams, 1990), and university patents are more frequently and generally cited than average patents (Henderson *et.al*, 1998). These spillovers promote growth and local industry development (Blomström and Kokko, 2003). Moreover, research for the USA suggests that knowledge spillovers originating from public knowledge institutions tend to be more localized than those from industry (Mansfield and Lee, 1996; Adams, 2001; Keller, 2002).

R&D co-operation between publicly funded institutions and private firms is considered an important avenue in converting publicly funded basic research into commercialized innovations, technological progress and productivity growth. Governments in OECD countries strive to integrate universities, public research institutes and all other actors in the national innovation system into a balanced entity permeated with cooperation and knowledge spillovers (Mowery and Sampat, 2005). For example, in Finland the integration of university activities into other parts of the

national innovation system is an explicit feature of Finnish innovation policy (Nieminen and Kaukonen, 2001).

2.3 R&D internationalization and the national innovation system

Until the mid-1980s, innovation processes in MNEs took mainly place at the headquarters in the home country. Overseas technological activity was adaptive and strongly dependent on the centralised knowledge base at headquarters (Dunning, 1988; Patel and Pavitt, 1991). From the mid-1980s onwards, R&D facilities in foreign locations were strengthened to explore host country R&D facilities and to tap into their national innovation systems (Patel and Vega, 1999). Rising R&D costs and competitive pressure pushed international firms to increasingly work in research alliances with customers, competitors or universities and public R&D institutes (Dunning, 1994). E.g., Archibugi and Iammarino (1999) have argued that mounting globalisation of innovation and technology has raised collaboration between domestic and foreign actors. R&D capabilities of host countries have become an important location-specific characteristic motivating FDI (Cantwell and Iammarino, 2003; Blomström and Kokko, 2003).

Sanna-Randaccio and Veugelers (2002, 2003) provide theoretical analyses of the benefits and costs of R&D decentralization for an MNE. Beneficial incoming external knowledge spillovers to the subsidiary are weighed against outgoing information leakages. They argue that the net outcome of incoming spillovers for foreign firms improves when local partners are public knowledge institutions and the know-how of a fundamental character.

Several empirical studies have investigated the internationalisation strategies of MNEs in R&D. Almeida (1996) has investigated foreign firms in the US semi-

conductor industry. He found them to seek technology by investing locally, and to contribute to local technological progress. Foreign subsidiaries in the United States use and contribute to local knowledge at the regional level as well as at the country level though to a much lesser extent. Nobel and Birkinshaw (1998) have identified various motives for internationalising R&D, and access to scientific talent is one of them. Von Zedtwitz and Gassmann (2002) found the proximity of local universities and research parks to be an important determinant for MNEs' R&D decentralization abroad.

Although both domestic and foreign innovating firms are increasingly internationalising their research activities, R&D is still one of the least mobile activities of MNEs. Advanced technical knowledge is complex, which makes it costly to fragment R&D and locate it in different places. Moreover, the tacit character of such knowledge requires that research needs face-to-face contacts to exchange information and ideas (World Investment Report 2005: 157). Le Bas and Sierra (2002) investigated 345 MNEs with the greatest patenting activity in Europe and found that in nearly 70 % of the cases, MNEs invest abroad in technological areas in which they enjoy a competitive advantage on their home market. Tidd, Bessant and Pavitt (2005: 212-213) argue that in the 1990s more than 85 % of the innovative activities of 359 of the world's largest firms are located in the home country. In other words, there is certainly a tendency of increased R&D internationalisation, but MNEs seem to prefer innovative activities in the home markets over host markets although to a lesser extent than in the 1970s and 1980s.

3. Hypotheses

Knowledge interaction between private firms and public knowledge institutions can take several forms ranging from loose direct personal contacts to formalized interaction like co-operation in research consortia (Schartinger *et.al*, 2002). In this paper our focus is on formal partnerships in which innovating firms actively, and together with universities and other public R&D institutes, develop technologically new or improved products and/or production processes.[2]

As argued in subsection 2.3, R&D internationalization through MNEs has increased in the last decade, although MNEs still seem to prefer co-operation with home country universities and public research institutes. To attract innovating foreign firms, host countries have to compete with each other based on their advantages, be it a large market, financial incentive policies or a high quality innovation system. This makes the knowledge relationship between foreign firms and domestic public knowledge institutions more elastic than it is with innovating domestic firms. It can therefore be expected that foreign firms' probability to co-operate with domestic universities and other public R&D institutes in the host country is lower than that of domestic firms.

Hypothesis 1. The probability for innovating foreign firms to co-operate with host countries' public knowledge institutions is lower than it is for innovating domestic firms.

International firms have always used R&D to adapt technologies and products to local conditions in the host countries. Recently, MNEs also aim for setting up R&D

[2] Excluding outsourcing of R&D activities to domestic public knowledge institutions.

facilities abroad in order to search for new knowledge and technologies. Laursen and Salter (2004) suggest to measure searching behaviour by an "openness" variable, which measures the degree to which firms seek to draw in new knowledge and to re-use existing knowledge from external sources (Laursen and Salter, 2004: 1204). Cassiman and Veugelers (2002) use a more limited concept of openness by restricting it to openness to incoming horizontal spillovers. In order for innovation policies – aimed at reducing access barriers to research done by universities and public knowledge institutes – to be effective it is important that innovating firms' consider incoming knowledge spillovers a relevant stimulus for R&D co-operation with public knowledge institutions. We expect that innovating firms, experiencing incoming horizontal knowledge spillovers, are encouraged to co-operate with domestic universities and public R&D institutes due to an increase in the scope for learning between partners (Cassiman and Veugelers, 2002: 1172).

Hypothesis 2. Incoming horizontal knowledge spillovers of innovating (domestic and foreign) firms endorse their R&D collaboration with public knowledge institutions.

Innovation policies' most direct point of application is the domestic public knowledge institutions, which provide academic and basic knowledge. Innovating firms' principal incentive for R&D collaboration with universities and other public R&D institutes is to gain access to knowledge they cannot provide themselves, particularly academic or basic research. We assume that innovating firms that use basic knowledge more often than applied knowledge for their innovation projects are more inclined to co-operate with public knowledge institutions.

Hypothesis 3. If innovative (domestic and foreign) firms use more basic than applied knowledge for their innovations, they are inclined to co-operate more with public knowledge institutions.

4. Model and model operationalization

4.1 The Model

The three hypotheses formulated lead us to specify a model on the determinants of R&D collaboration with public knowledge institutions. The model is formulated in (1).

$$Cooperation = \beta_0 + \beta_1 MNE + \beta_2 External\_source + \beta_3 External\_source * MNE + \\ + \beta_4 Basic + \beta_5 Basic * MNE + \beta_6 Internal\_source + \beta_7 \ln(Size) + \beta_8 R\&D + \beta_9 Barriers \\ + \beta_{10} Sector + \beta_{11} Other + \varepsilon \qquad (1)$$

The dependent variable is R&D co-operation between innovating firms and domestic universities and/or public R&D institutes. Hypothesis 1 is tested by the variable *MNE*, which describes whether the firm is foreign or domestic. A negative impact of this variable on *Cooperation* is expected. Hypothesis 2 is tested with the *External_source*-variable. It is a measure for how open innovating firms are to external or incoming knowledge spillovers as a source for innovative ideas. It is expected to be an incentive for them to co-operate with domestic universities and public R&D institutes (Cassiman and Veugelers, 2002: 1171). Whether or not a firm is open to these spillovers is a management decision.[3] The third determinant is a cross product of the

[3] Laursen and Salter (2004) also define an openness variable but they are interested in all sources of information while we follow Cassiman and Veugelers (2002) by defining horizontal incoming spillovers as these are considered as more important than vertical incoming spillovers.

incoming knowledge spillovers with the *MNE*-variable and shows whether and how foreign firms deviate from domestic firms with regard to this explanatory variable.

The kind of innovations (*Basic*) explains the importance of basic knowledge use in the innovation process relative to the use of applied knowledge and deals with the third hypothesis. Universities and public R&D institutes are particularly attractive for innovating firms that need basic knowledge. This variable is assumed to affect co-operation positively. The cross product of *Basic* with *MNE* aims to estimate a separate effect for foreign firms.

The variable *Internal_source* is included as a control variable that takes into account the impact of outgoing knowledge spillovers – from the innovating firm to its external knowledge environment – on co-operation with public knowledge institutions. It measures whether or not the information source of the innovation projects comes from inside the firm. A firm that innovates based on information developed inside the firm is expected to co-operate less with external partners as it prefers to use proprietary relevant and strategic knowledge, and not share it with external partners. Hence a priori we expect a negative impact of this variable on *Cooperation*.

Other variables that can be assumed to influence the dependent variable are also incorporated. The size of the firm is in many studies considered as a relevant determinant of R&D collaboration with public knowledge institutions (Laursen and Salter, 2004; Schartinger et.al, 2001). Larger firms have more means to spend on fundamental research and are therefore better able to use knowledge of universities and public research knowledge institutes. Furthermore, large firms also employ more staff with an academic background in science and engineering. This is a channel through which relationships with universities are relatively easy to establish and to maintain. A positive effect is expected for the *Size*-variable.

R&D-intensity measures whether or not a firm invests intensively and frequently in R&D. Own knowledge or 'absorptive capacity' needs to be high enough to transform the fruits of R&D co-operation with public knowledge institutions to commercial use (Cohen and Levinthal, 1989; Mohnen and Hoareau, 2003). A positive coefficient is expected.

Potential barriers to innovation are numerous and impacts varying. The barriers-to-innovation variables are 1) organizational barriers, 2) barriers due to uncertainty with regard to sales and finance, 3) cost barriers. Organizational barriers are generally expected to affect R&D co-operation negatively because they divert management's attention away from external knowledge sources. The other two barriers can provide incentives to set up R&D collaboration schemes with either private or public parties as co-operation results in sharing R&D-costs.

The *Sector* variables are sector dummies to correct for the sector structure. The variable *Other* is the sector average of these two variables. Some authors (Cassiman and Veugelers, 2002; Cohen and Levinthal, 1989) have argued that including sector averages of qualitative variables like *External_source* and *Internal_source* reduces the problem of subjectivity and hence measurement errors.[4]

4.2 Model operationalisation

The operationalisation of the model variables as specified in (1) is based on the questions in the CIS-questionnaires (see also Table A.1 in Annex A). The dependent variable *Cooperation* is 1 if a firm co-operates on R&D-efforts with domestic universities and public R&D institutes and 0 otherwise. The co-operation is a formal

[4] Both *External_source* and *Internal_source* are qualitative variables with a scale of 1 − 4. These values are filled in by individual respondents that might differ in their use of this four-point scale. See subsection 4.2 for operationalisation of these variables.

active participation of both the innovating firms and public knowledge institutions in a joint R&D project.

In order to eliminate causality problems, the independent variables are included with lags except for *MNE* and *Sector* (sectoral dummies). The first determinant of R&D co-operation (*MNE*) is whether the firm is an affiliate of a foreign firm (*MNE* = 1) or not (*MNE* = 0) in the period in question. The second independent influence is incoming horizontal knowledge spillovers (*External_source*). These are defined as information from analyses of competitor's products, investigations of existing patents and external databanks and investigations from scientific journals, ranging from 1 to 4, i.e., it takes the value of 1 (not used), 2 (limited important), 3 (important) or 4 (very important). The scores on each of the questions were summed and re-scaled to a number between 0 and 1. Firms that use these information sources are assumed to be more open to incoming knowledge spillovers than firms that do not (Cassiman and Veugelers, 2002). This attitude increases the probability to co-operate with partners like universities and public R&D institutes.

Whether the kind of knowledge (fundamental or applied) is relevant, is tested by the basicness variable (*Basic*), which refers to the logarithm of the ratio of basic to applied innovations. This variable was introduced by Cassiman and Veugelers (2002) and the ratio's numerator is the sum of scores (1 = unimportant; 5 = crucial) of information sources from universities, public research institutes and technical research institutes. The denominator is defined as the sum of scores (1 = unimportant; 5 = crucial) of information sources from suppliers of materials, suppliers of equipment and customers. Basic research diffuses more easily than applied research and firms that consider sources of basic R&D more important than information sources of applied R&D, benefit more from incoming spillovers of basic research (Cassiman and

Veugelers, 2002: 1173). A positive effect of *Basic* on *Cooperation* means that a stronger focus on innovations that require more basic research compared to applied research, increases the probability to co-operate with public knowledge institutions.

The sixth variable describes outgoing knowledge spillovers and is defined as whether or not the information source of the innovation comes from inside the firm (*Internal_source)*. This variable also takes values from 1 to 4. Just like *External_source* this measure is also constructed by summing the scores on each question and re-scaling the total scores to a number between 0 and 1. It is expected to affect the probability to co-operate with universities or public knowledge institutes negatively.

Firm size (*Size*) is measured by the natural logarithm of the firm's turnover in the previous period. The variable *R&D* consists of two variables: (i) R&D-intensity, defined as R&D employees' share of the total number of employees in a firm, and (ii) R&D-permanence, which is a dummy variable that takes value 1 if the firm performs R&D every year, and 0 otherwise. Nieminen and Kaukonen (2001: 71) suggest that the more firms invest in in-house R&D, the more they are involved in R&D co-operation schemes with universities.

The CIS questionnaires also ask whether or not innovating firms experienced barriers to their innovation projects. Three barriers to innovation are distinguished, organizational (*Orgimp*), financial (*Finsalunc*) and cost barriers (*Costimp*). These are measured as a score variable with values 0 (no barriers experienced), 1 (barriers with slight negative impact), 2 (barriers with a negative impact) and 3 (barriers with a strong negative impact).

The variable *Sector* describes the impact of the sector structure on the probability to co-operate and consists of five dummy-variables of which three refer to the Pavitt

(1984) sector classification. As described by Pavitt (1984), science-based industries such as chemicals or electronics are heavily dependent on knowledge, skills and techniques from academic research. In scale-intensive industries such as extraction and processing of bulk materials or automobiles, technological progress consists mainly of incremental technological improvements in complex production processes and complex products. The design, building and operation of complex production processes and/or products are considered as the main source of technological accumulation. In specialized supplier industries, such as machine tools or software, technological progress has been fast, but based on incremental improvements. Most of the companies are small and provide high performance inputs into complex production systems.[5] The other two sector variables are only relevant for the services sector. These refer to value added services (financial, ICT and engineering) and pre-specified services (utility, trading, construction and other services).

5. Data

We have identified two countries sufficiently comparable in market size and economic development, Finland and the Netherlands. Furman *et al.* (2002) have shown that a higher level of economic development correlates strongly with national innovative capacity. Apart from differences in innovation policies and sector structures, the innovative capacities of Finland and the Netherlands are expected to be equally attractive to foreign firms at the aggregate level. Their most important similarities and differences are reported in Table 1.

[5] Pavitt (1984) defines as a fourth category called 'supplier-dominated industries', with textiles as a typical example. In these industries, suppliers drive technological change. The relative importance of this category is captured by the constant term.

INSERT TABLE 1

Table 1 presents some macro data on R&D and MNE investments in Finland and the Netherlands compared with three large economies Germany, UK and USA. The share of foreign assets in total investment is clearly higher in the Netherlands revealing the predominance of foreign firms in the Dutch economy. As the third column in Table 1 shows, the Finnish economy is more high-technology manufactures-oriented, while in the Netherlands the share of total value added originating from high-technology sectors is low, also in comparison to the larger economies. This is also reflected in R&D-expenditures as a share of valued added of domestic Dutch manufacturing firms, which is substantially lower than that of domestic manufacturing firms in Finland.[6] However, in the case of foreign MNEs, this variable is only slightly different between the two countries. This suggests that Finland's relative strength in high-technology sectors has been weakly translated into R&D-intensive foreign investment (contrary e.g. to Pajarinen and Ylä-Antilla, 2001). All countries in Table 1 show that R&D expenditures of foreign firms, as a share of their value added, are lower than those of domestic firms. This corresponds to the observation that most R&D expenditures are still spent in the home markets (see subsection 2.3).

The micro-data used for the analysis are drawn from CIS-questionnaires of Finland and the Netherlands. The European Community CIS-questionnaires consist of questions on innovative behaviour of firms. Although these questions are harmonized among the participating European countries, and therefore provide researchers with exceptionally comparable data, few researchers have used this option (mostly due to

[6] Finnish R&D is dominated by the electronics sector and within it, by Nokia (see also Daveri and Silva, 2004).

practical problems). Many studies carried out on CIS data focus on one country.[7] We compare at the micro-level between two small open countries, Finland and the Netherlands.

As our main goal is to explain R&D collaboration between innovating firms and public knowledge institutions, we use innovative firms from these representative CIS-datasets to construct our sample.[8] Firms are innovative if they report that they produced technically improved or new products and/or use technically new or improved production processes in the years 1996-1998 and 1998-2000. In the Finnish case, 210 observations of innovating firms' data for the years 1996-1998 and 1998-2000 are available. In the Dutch situation, the number of observations is 1134.

Table 2 shows the percentages of innovating domestic and foreign firms being permanent innovators and the percentual share of innovating firms that work "actively and in co-operation with public knowledge partners on the development of technologically new or strongly improved products".

INSERT TABLE 2

A first observation is that the share of permanent innovators in the total number of innovators is higher in Finland (> 76 %) than in the Netherlands (< 53 %). This is in line with the relatively strong specialization of Finland in high-technology production. Second, in Finland the share of innovating domestic and foreign firms that are involved in R&D collaboration schemes with domestic public knowledge institutions is five times higher than in the Netherlands.

[7] One of the exceptions is Mohnen et.al (2006).
[8] CIS-data are collected by national statistics offices.

The relatively high shares of innovators with public R&D collaboration schemes in Finland can be accounted for by two factors. First, the Finnish economy is structurally more dominated by high and medium technology firms than that of the Netherlands, which is a more service-oriented economy. It can be expected *a priori* that high and medium technology industrial firms co-operate more intensively with public knowledge institutions than other firms. (Castells and Himanen, 2002)**.** Second, Finnish innovation policies have strongly encouraged co-operation among all relevant players within the national innovation system. The National Technology Agency of Finland (TEKES) supports R&D in companies based in Finland and Finnish research institutes and universities. Networking and co-operation between universities and industry is a central funding criterion irrespective of whether a firm is of domestic or foreign origin (Castells and Himanen, 2002).

In contrast, the Dutch approach has been concentrated on general innovation policies through financial instruments like tax credits that address firm's production costs. Also national agencies exist – SENTER and SYNTENS - granting technology subsidies to firms. A gradual change took place with the establishment of so-called Top Technological Institutes in 1997. These are institutes in four scientific fields (material science, food science, polymer science and telematics) in which private firms and scientific organizations co-operate on fundamental research that should be made applicable in the longer term. Although networking and R&D collaboration between firms and public knowledge institutions play a role as conditions for some subsidies, they are not applied with a fully integrated national innovation system as in Finland (Hjerppe and Kiander, 2004).

In Table 3, mean and standard deviation descriptives of some relevant independent variables are reported.

INSERT TABLE 3

In Finland, the average values of innovative firms' *Size*-variables are higher than in the Netherlands. In both countries foreign firms are larger than domestic firms, and particularly in Finland, the small standard deviation reveals that nearly all firms of foreign origin in the sample are large ones. The average *R&D-intensity* in Finland is between 7 and 10 % and between 2 and 3 % in the Netherlands. This is consistent with higher R&D expenditures as a share of value added in the manufacturing sector in Finland as shown in Table 1.

The average scores of *External_source* are lower than those of *Internal_source* in both countries. Comparison between the two countries shows that the average scores on *External_source* are higher in Finland than in the Netherlands. This suggests that innovating firms in Finland are more open to incoming knowledge spillovers than innovating firms in the Netherlands. For the *Internal_source*-variable the same pattern can be observed, but the differences between the two countries are smaller especially with regard to foreign firms.

The *Basic*-variable shows that this ratio is on average higher in Finland. Foreign firms are on average more involved in basic research than domestic enterprises. The small standard deviation in Finland shows that this is valid for nearly all foreign enterprises in the sample.

6. Econometric results

In order to enter into R&D-partnering, firms have to be innovative. Therefore the empirical analysis is restricted to innovative firms. As we are interested in the

relationships between innovative firms and public knowledge institutions, our analysis is only valid for innovative firms.

Two datasets of innovative firms were constructed from the Dutch and Finnish Community Innovation Surveys. Survey data on the year 1998-2000 (CIS-3) represent the current year. The lagged variables refer to 1996-1998 survey data (CIS-2). As we select firms that are innovative in both 1996-1998 and 1998-2000, we introduce a selection problem that can affect the estimates. Descriptive statistics of relevant economic indicators show that firms represented in both CIS-2 and CIS-3 are on average significantly larger than firms represented in CIS-3 only.[9] Therefore we estimate model (1) with a Heckman corrected probit procedure to correct for this possible selection bias.[10] The selection equation is a probit estimation of a dummy with value 0 if an innovative firm is present in 2000 only, and value 1 if it is present in both 1996 and 2000 on the natural logarithm of the firm's sales in 2000. The results are shown in Table 4. The variables of main interest are *MNE*, *External_source*, and *Basic*.

INSERT TABLE 4

Regression 1 shows that foreign ownership status does affect the probability to co-operate with Finnish universities and public R&D institutes positively, but not significantly (*MNE*). In the Dutch case (regression 3) the effect of innovating foreign firms on R&D-collaboration is negative. Although not significant, it suggests that innovating firms of foreign origin in the Netherlands have a lower probability to co-

[9] For the sake of brevity, these descriptives are not reported, but are available upon request from the authors.

[10] Restricting the sample to innovative firms only might lead to another selection bias if co-operation would be the only strategy to innovate for firms that would otherwise not be innovative. This is quite unlikely and discussed in Cassiman and Veugelers (2002).

operate in their R&D efforts with Dutch public knowledge institutions than domestic firms. Hypothesis 1 should be rejected for Finland.

The lack of a negative effect in Finland can be explained by Finnish innovation policies and/or the Finnish sector structure, which is more inclined towards R&D-intensiveness than the Dutch economy. As the sector dummies control for it, it is likely that innovation policies explain remaining differences.[11]

Incoming horizontal knowledge spillovers are an important determinant for co-operation with public knowledge institutions (*External_source*). Ideas from outside the firm affect innovative firms' co-operation with Finnish public knowledge institutions positively, but not significantly. In the Dutch case the coefficient of this variable is positive as well, and significantly different from zero. For the Netherlands hypothesis 2 cannot be rejected. These findings imply that if managers in both countries follow strategies that open their firms to incoming knowledge spillovers, it would result in a higher probability to collaborate on R&D with public knowledge institutions. This is in line with results of Laursen and Salter (2004) for the United Kingdom.

The cross product of *External_source* with *MNE* attempts to filter out whether incoming knowledge spillovers to innovating foreign firms provide an additional stimulus for co-operation with public knowledge institutions. In Finland, the estimated coefficient for *MNE* is 1.291 ($\beta_2 + \beta_3$), which is higher than the coefficient for domestic firms, i.e. 0.886 (β_2). Although these coefficients are not significant, they do cautiously suggest that in Finland the impact of incoming knowledge spillovers on foreign firms' probability to co-operate with public knowledge institutions is higher than it is for domestic firms. This is not found for the Netherlands.

[11] This conclusion is suggestive. A better test would be to combine the Dutch and Finnish dataset and use a country-dummy. This is not possible as CIS data are collected by national statistical offices and – for the time being – unavailable for pooling with other countries.

The small positive, though insignificant, effect of the *Basic*-variable in regression 1 shows that in innovating firms in Finland the need of basic research is barely more important than applied research in explaining their probability to co-operate with domestic public knowledge institutions. The *Basic*-variable in the third regression is positive and significant, which implies that innovating firms requiring basic research have a higher probability to co-operate with Dutch universities and public R&D institutes. Hypothesis 3 is rejected for Finland and cannot be rejected for the Netherlands.

The cross products of *Basic* and *MNE* show that the requirement of basic knowledge by foreign firms is not a significant additional explanation. It is slightly positive in Finland and slightly negative in the Netherlands.

A significant positive effect of *Internal_source* or outgoing knowledge spillovers on the probability to co-operate with domestic public knowledge institutions is shown for Finland, i.e. innovative ideas that originate in the innovating firms increase the probability to co-operate with Finnish universities or public R&D institutes. It suggests that innovative firms consider Finnish universities and public knowledge institutions useful R&D partners for academic, as well as applied research. This finding is in contrast with a priori expectations, which assume a negative relationship as found for the Netherlands although this estimate is not significant.[12] Finnish science and technology policies that use networking and co-operation between universities and industry as a central funding criterion reduce access barriers to knowledge in universities and public knowledge institutes. As a consequence, innovating firms are provided with more information on the usefulness of the

[12] The predominance of the service sector in the Netherlands cannot explain this result. Restricting regression 3 to the manufacturing sector does not change the results. E.g., the coefficients become 0.456 (*External_source*), –0.125 (*Internal_source*) and 0.212*** (*Basic*). Regressions restricted to the manufacturing sector are available upon request from the authors.

available knowledge in these institutions and hence become willing to share information with public R&D partners.

In the Netherlands the opposite result is found. The negative sign of *Internal_source* in the Dutch estimates indicate that firms seem not to be willing to share their proprietary knowledge with universities and public research institutes. Although innovating firms that consider basic R&D more important than applied R&D, are more inclined to co-operate with Dutch universities and public knowledge institutes, they are reluctant to co-operate with universities and public research knowledge institutes when the innovative ideas originate within the firm. This suggests that although the need for academic research and spillovers are an important incentive to co-operate, foreign and domestic innovating firms in the Netherlands are reluctant to share their internally developed knowledge and ideas with public knowledge institutions.

As expected, the size variable is positive. The insignificance for the Netherlands results from the Heckman correction.[13] *R&D intensity* is positive, showing it as an important factor in cooperation with public knowledge institutions in both countries. *R&D-permanence* is positive and significant in the Dutch case, but in the Finnish regression it is slightly negative. This suggests that in Finland, firms that produce innovations continuously do not co-operate more with universities and public R&D institutes than firms that innovate incidentally. This is consistent with the provision of R&D subsidies in Finland being conditional on R&D co-operation and networking with domestic universities, which removes impediments for incidentally performing firms.

[13] If the regressions were run with a simple probit procedure, the coefficients remain the same except for the size variable, which is significantly positive in the simple probit model. The stability of the relevant coefficients has been tested with a Hausmann test.

Organisational barriers to innovations affect the probability to co-operate with domestic public knowledge institutions negatively in the Finnish case and positively in the Dutch regressions. However, the results are not significant. Insignificant results are also found for finance/sales- and cost barriers.

The Pavitt dummies show insignificant results for the science dummy in the Netherlands, which cannot be attributed by multicollinearity. In Finland the science dummy affects the dependent variable positively. Multicolinearity is found for the *Science*-dummy, but not for the *Basic*-variable.[14]

Innovating firms in the specialized supplier sector (*spectoel*) in the Netherlands, co-operate less on R&D with Dutch public knowledge institutions than the average. In Finland this estimate is positive and significant. Firms in this sector require applied knowledge, which they can get from Finnish universities, but much less from Dutch universities and public R&D institutes, as can be observed by the different coefficients of the *Basic*-variable. The negative significant estimates for the service sector dummies *Va* and *Pespec* in the Netherlands reveal that firms in the important service sector do not co-operate in R&D with universities and public R&D institutes.

The variables *A_external_source* (= average of *External_source*-variable) and *A_internal_source* (= average of *Internal_source*-variable) show no significant effects on the dependent variable.

7. Conclusions and questions for further research

The purpose of this paper has been to examine the determinants of R&D co-operation between innovating firms and domestic public knowledge institutions in Finland and the Netherlands, with a special emphasis on foreign affiliates. Both countries were

[14] Variance Inflation Factor (VIF) for the science dummy in Finland (Netherlands) is 3.81 (1.50) and for the *Basic*-variables in Finland (Netherlands) VIF = 1.16 (1.03).

compared with harmonized data from two waves of Community Innovation Survey (CIS-) data (1996 and 2000).

Our results show that as expected, foreign firms are less involved in R&D co-operation with public knowledge institutions than domestic firms in the Netherlands. For Finland this is not the case. We suggest cautiously that Finnish innovation policies – with strong incentives to stimulate co-operation with universities and public knowledge institutes – might play an important role in explaining this. In order for such innovation policies to be effective it is necessary that innovating firms 1) experience incoming knowledge spillovers, and 2) require academic or basic knowledge R&D in developing innovations. Only then the theoretically expected high benefits of academic knowledge spillovers for economic growth can materialize. In both countries incoming knowledge spillovers affect the probability to co-operate with universities and public knowledge institutes positively. Weak evidence was found that in Finland foreign firms' incoming knowledge spillovers affect the probability for R&D co-operation with public knowledge institutions more positively as compared with domestic firms.

Our study also shows that stronger basic knowledge needs relative to applied knowledge, is an important stimulus for innovating firms in the Netherlands to co-operate with Dutch public knowledge institutions. In Finland basic knowledge and applied knowledge are equally relevant as a stimulus for co-operation with Finnish public knowledge institutions.

Another observation is that – in contrast to expectations – in Finland innovating ideas developed within the walls of the firms stimulate R&D collaboration with domestic universities and public knowledge institutes. As the innovating firms' motives for these co-operation schemes in Finland are less governed by the need for

academic research spillovers, they do consider co-operation with universities and public research institutes relevant for developing their own ideas further. Finnish innovation policies aimed at reducing access barriers to academic knowledge, might contribute to this result. In the Netherlands, although the need for academic research and spillovers are an important incentive to co-operate, foreign and domestic innovating firms are reluctant to share their proprietary knowledge with public knowledge institutions.

Some questions are left for further research. First, in this paper we assume implicitly that universities and public research institutes in Finland and the Netherlands are more or less comparable, providing the same type of knowledge and with the same attitude towards co-operation with the private sector. The result that Finnish innovating firms' R&D co-operation with domestic public knowledge institutions is not stimulated when the innovations are fundamental, raises the question whether Finnish innovation policies provide (implicit) incentives for these institutes to put more emphasis on applied work. In order to receive R&D subsidies, firms and domestic public knowledge institutions might behave strategically. To shed more light on this policy issue, it is recommendable to investigate it from the perspective of universities and public R&D institutes. The focus of the present study was on the perspective of private innovative firms only.

Second, the finding that innovating firms seem not to be willing to share their proprietary knowledge with Dutch universities and R&D institutes, induces the question in which sectors the mismatch takes place and what policies should be modified to improve knowledge exchange between public knowledge institutions and private firms. Further investigation at the sectoral level is necessary to deal with this issue.

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Table 1. R&D- and MNE data in a comparative setting

	Inward FDI as % of total gross investment averages 1997-2002	High and medium high technology manufactures share in total value added (%), 2000	R&D-expenditures as share of value added in domestic manufacturing firms, 2001	R&D-expenditures as share of value added in foreign manufacturing firms, 2001
Finland	20.2	11.10	2.89	0.48
Netherlands	46.1	5.98	1.32	0.36
Germany	15.1	11.70	2.19	0.51
UK	28.2	7.29	1.14	0.74
USA	11.2	7.87	2.37	0.40

Sources:
- World Investment Report 2005 for "inward FDI as % of total gross investment",
- OECD Technology and Industry Scoreboard, 2005 for the other columns

Table 2. Permanently innovating firms and R&D collaboration schemes with public knowledge institutions: percentages of domestic and foreign innovators in Finland and the Netherlands (1996 and 2000).

	Finland		Netherlands	
	Domestic	Foreign	Domestic	Foreign
Permanent	76	83	49	53
R&D collaboration with domestic public knowledge institutions	53	66	11	12

Source: Community Innovation Survey databases of Finland and the Netherlands: years 1996 and 2000.

Table 3. Descriptive statistics: means and standard deviations of innovative firms

	Size		*R&D-intensity*		*External_source*		*Internal_source*		*Basic*	
	mean	s.d	mean	s.d	mean	s.d	mean	s.d.	mean	s.d
					Finland					
All	11.41	1.75	0.08	0.12	0.39	0.17	0.57	0.23	-0.70	0.63
Domestic	11.35	1.49	0.07	0.12	0.39	0.17	0.55	0.23	-0.72	0.65
Foreign	11.79	0.21	0.10	0.15	0.40	0.17	0.66	0.24	-0.56	0.08
					Netherlands					
All	9.93	1.46	0.02	0.06	0.23	0.17	0.49	0.25	-0.87	0.87
Domestic	9.76	1.43	0.02	0.06	0.23	0.16	0.46	0.24	-0.88	0.87
Foreign	10.45	1.45	0.03	0.07	0.26	0.19	0.59	0.26	-0.84	0.86

Notes: *s.d. = standard deviation*

Table 4. Heckman probit estimates of co-operation with domestic public knowledge institutions in Finland and the Netherlands: all sectors in 1996 and 2000.

Regression		1	2	3	4
Meaning	Variable	Finland		Netherlands	
	Constant	*-5.894****	*-5.912****	*-1.597*	*-1.748*
		(3.287)	*(3.282)*	*(1.444)*	*(1.486)*
MNE	MNE_t	*0.134*		*-0.134*	
		(0.306)		*(0.090)*	
Incoming Spillovers	$External\_source_{t-1}$	*0.927*	*0.886*	*0.472**	*0.506**
		(0.673)	*(0.683)*	*(0.263)*	*(0.269)*
	$External\_source_{t-1} * MNE_t$		*0.405*		*-0.070*
			(0.982)		*(0.089)*
Academic Knowledge	$Basic_{t-1}$	*0.046*	*0.038*	*0.241****	*0.281****
		(0.180)	*(0.187)*	*(0.059)*	*(0.085)*
	$Basic_{t-1} * MNE_t$		*0.059*		*-0.071*
			(0.525)		*(0.101)*
Outgoing Spillover	$Internal\_source_{t-1}$	*1.425****	*1.417****	*-0.125*	*-0.123*
		(0.548)	*(0.550)*	*(0.198)*	*(0.200)*
Size	$Ln(Sales_{t-1})$	*0.374***	*0.380***	*0.042*	*0.046*
		(0.189)	*(0.190)*	*(0.081)*	*(0.082)*
R&D	$R\&D\text{-}intensity_{t-1}$	*3.167***	*3.183***	*1.584***	*1.608***
		(1.271)	*(1.276)*	*(0.627)*	*(0.632)*
	$R\&D\text{-}permanent_{t-1}$	*-0.091*	*-0.091*	*0.191**	*0.194**
		(0.275)	*(0.278)*	*(0.108)*	*(0.109)*
Barriers	$Orgimp_{t-1}$	*-0.955*	*-0.970*	*0.108*	*0.105*
		(1.019)	*(1.026)*	*(0.282)*	*(0.285)*
	$Finsalunc_{t-1}$	*0.714*	*0.707*	*-0.090*	*-0.082*
		(0.759)	*(0.760)*	*(0.177)*	*(0.179)*
	$Costimp_{t-1}$	*0.030*	*0.045*	*-0.076*	*-0.085*
		(0.986)	*(0.990)*	*(0.392)*	*(0.397)*
Sector	$Science_t$	*0.739**	*0.744**	*-0.221*	*-0.233*
		(0.400)	*(0.401)*	*(0.219)*	*(0.222)*
	$Scale_t$	*-0.163*	*-0.167*	*-0.156*	*-0.162*
		(0.354)	*(0.355)*	*(0.123)*	*(0.124)*
	$Spectoel_t$	*0.518**	*0.524**	*-0.354***	*-0.362***
		(0.315)	*(0.313)*	*(0.170)*	*(0.172)*
	Va_t	*0.400*	*0.361*	*-0.562***	*-0.578***
		(0.874)	*(0.895)*	*(0.236)*	*(0.240)*
	$Pespec_t$	*-0.679*	*-0.709*	*-0.482*	*-0.486*
		(0.703)	*(0.731)*	*(0.157)*	*(0.158)*
Other	$A\_External\_source_{t-1}$	*0.096*	*0.095*	*-0.408*	*-0.375*
		(2.401)	*(2.401)*	*(1.286)*	*(1.297)*
	$A\_Internal\_source_{t-1}$	*1.069*	*1.028*	*0.786*	*0.803*
		(1.408)	*(1.426)*	*(0.921)*	*(0.930)*
	rho	*-0.362*	*-0.369*	*-0.653***	*-0.642***
		(0.630)	*(0.633)*	*(0.233)*	*(0.241)*
	Log-likelihood	*-503.354*	*-503.343*	*-2397.792*	*-2397.792*
	Number of observations	*789*	*789*	*3502*	*3502*
	Uncensored observations	*210*	*210*	*1134*	*1134*

Notes: * = significant at 10 %
** = significant at 5 %
*** = significant at 1 %

Annex A

Table A.1. Explanation and operationalisation of variables.

Meaning	Variable	Operationalisation
Dependent		
Cooperation	$Cooperation_t$	Dummy variable with value 1 if firm co-operates with domestic public knowledge institutions in period t and 0 otherwise
Independent		
MNE	MNE_t	Dummy variable with value 1 if the firm is part of a foreign concern and 0 otherwise in period t
Incoming spillover	$External\_source_{t-1}$	Source of idea for innovation from outside the firm in period t-1. Score variable ranging from 1 (not used) – 4 (degree of use is high)
Academic knowledge	$Basic_{t-1}$	natural logarithm of the ratio of fundamental to applied innovations in period t-1
Outgoing spillover	$Internal\_source_{t-1}$	Source of idea for innovation from inside the firm in period t-1. Score variable ranging from 1 (not used) – 4 (degree of use is high)
Size	$Ln(Sales)_{t-1}$	natural logarithm of firm's turnover in period t-1
R&D	$R\&D\ intensity_{t-1}$	R&D employees as fraction of the firm's total employees in period t-1
	$R\&D\ permanent_{t-1}$	Dummy variable with value 1 if firm innovates every year and 0 otherwise in period t-1
Barriers	$Orgimp_{t-1}$	Organizational barriers to innovations in period t-1. Score variable ranging from 0 (not perceived) – 3 (strong barrier)
	$Finsalunc_{t-1}$	Barriers to innovations due to uncertainty with regard to sales and finance in period t-1. Score variable ranging from 0 (not perceived) – 3 (strong barrier)
	$Costimp_{t-1}$	Cost barriers to innovations in period t-1. Score variable ranging from 0 (not perceived) – 3 (strong barrier)
Sector	$Science_t$	Pavitt dummy with value 1 if firm belongs to Science Based sectors and 0 otherwise in period t
	$Scale_t$	Pavitt dummy with value 1 if firm belongs to Scale Intensive sector and 0 otherwise in period t
	$Spectoel_t$	Pavitt dummy with value 1 if firm belongs to Specialised Equipment Suppliers sector and 0 otherwise in period t
	Va_t	Dummy with value 1 if firm belongs to valued added services sector (financial, ICT and engineering) and 0 otherwise in period t
	$Pespec_t$	Dummy with value 1 if firms belongs to pre-specified services (utility, trading, construction and other services) and 0 otherwise in period t
Other	$A\_External\_source_{t-1}$	Average of "outside the firm" innovation source variable in period t-1
	$A\_Internal\_source_{t-1}$	Average of "inside the firm" innovation source variable in period t-1