Knowledge spillovers through RD networking

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1. Introduction

In spite of the abundant research on the relation between spillovers and the optimal outcome of co-operation in R&D versus non-co-operative set-ups, and the well-acknowledged increasing occurrence of co-operative agreements, the fact that firms could manage and increase spillovers through R&D co-operation has hardly been addressed empirically.

In this paper, we will show that the rationale for a policy of promoting R&D co-operation depends on the theoretical perspective that is endorsed, and on the magnitude and nature of spillovers, a matter that is still open to empirical scrutiny.

Public policies that are entirely based on conclusions from analysing existing national value added linkages may be more inward- and backward looking than those which also consider (inter)national collaborative patterns, that will partly shape the future economic and technological space.

Up to now, previous studies on the proxy measurement of spillovers focused mainly on supplier-buyer linkages or on patent data.

We have computed knowledge spillovers, using the linkages between firms that have been established in the EU through 'pre-competitive' collaborative R&D.
The European Framework Programmes (FWPs) is undoubtedly the most basic and popular mechanism through which public-funded collaborative research has been performed in Europe during the last two decades.

We have found that the pattern of intra- and intersectoral spillovers is country specific, more so for user sectors than for supplier sectors, and cannot simply be fitted in the value added chain.

The degree of intrasectoral spillovers is found to be relatively high and surprisingly significantly higher in large countries than in smaller countries.
This is a finding that should be examined more thoroughly as it could indicate collusive behaviour. Because of the 'pre-competitive' nature of the FWP projects and the theoretical advantages of co-operation at the R&D stage, this finding should not immoderately warn us against collusion, although there are some indications that the FWPs may have reinforced the oligopolistic tendency of the European IT market.

We argue that the mapping of R&D collaboration allows for a rather straightforward measurement of knowledge spillovers, that can complement or readjust some of the conclusions that have resulted from other methodologies.

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2. How embodied are knowledge spillovers ?

Technological or R&D spillovers are most often strictly defined as externalities (e.g. Grossman and Helpman, 1992) although more recent definitions also comprise the ***voluntary*** exchange of useful knowledge (e.g. Steurs, 1994; Llerena and Matt, 1999; Rycroft and Kash 1999; and De Bondt, 1999).

In his review of preceding research on R&D spillovers, Griliches (1992) concludes that, in spite of a considerable number of methodology and data constraints, studies generally seem to confirm the presence and relative magnitude of R&D spillovers.

Griliches makes the distinction between two notions of R&D spillovers.
He qualifies spillovers to be 'embodied' if they relate to the purchase of equipment, goods and services. Embodied spillovers can also be defined as rent spillovers to the extent that improvements-resulting from one firm's efforts- in the products that are sold to other firms are not fully absorbed by a concurring price increase.
Embodied spillovers are generally measured through input-output tables- amplified with survey data or data on R&D expenditures- or flows of international trade (Terleckyj 1974; Coe and Helpman 1995; OECD 1999 a).
Although the importance of supplier-buyer linkages for innovation is well-established (Debresson et al. 1997 ; Christensen, Rogaczewska and Vinding 1999; OECD 1999 b) innovative networks are also often found to be too complex to be reduced to value added chains.
Because, as pointed out by Debresson (1999), innovative networks often straddle nations and encompass foreign partners, the use of available R&D collaboration data can broaden the framework of interfirm networking by focusing both on national and international linkages whereas I/O analysis is mostly confined to national or regional networking.
Debresson and Hu (1999) find that I/O-based methods are in general not very reliable for small, open economies and are limited to mapping innovative activities within the « old economic space ».[3]
If public policy would only draw conclusions from this kind of analysis, it will probably be more inward- and backward looking than a policy that also considers indications as to the direction in which the international technological space will evolve.
An I/O-based policy may also run the risk of promoting inefficient and collusive lock-in situations.

We argue that an I/O-based approach is perhaps appropriate to analyse incremental changes, which undoubtedly are very important, but probably will take place, with or without any government support[4].
More breakthrough innovations, however, resulting from new combinations of complementary technological knowledge are rather unlikely to be grasped by existing value added links.
The high uncertainty involving fundamental innovations and their great welfare increasing consequences seem, far more than for incremental innovations, to call for specific policy measures and support.

Analysing (pre-competitive) R&D networking can be instrumental in this policymaking process, as well as in assessing the impact of network promoting policies.

Disembodied spillovers are seen by Griliches (1992: p. S 36) as " [...] *ideas borrowed by research teams of industry i from the research results of industry j. It is not clear that this kind of borrowing is particularly related to input purchase flows*" and are in his view more significant than embodied spillovers.
According to Griliches, the main problem with computing knowledge spillovers is an accurate definition of the technological proximity or closeness between firms, as an inverse relationship between spillovers and technological distance may be expected.

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[3] In most Input-Output tables data on imported goods are not broken down by sector of origin.
[4] Luukkonen (2001) found that for Finnish FWP participants vertical consortia had the lowest additionality.

Scherer (1982) constructed a matrix of technology flows by linking data from a 1974 business survey on R&D expenditures to patent data.

Jaffe (1986, 1989) proposes a method to characterize the technological position of a firm based on patent data, which allows for the detection of technologically related firms. In Jaffe's view the magnitude of spillovers is a function of the technological distance between firms.
He uses the distribution of firms' patents over patent classes and defines the spillover pool as the weighed sum of all other firms' R&D, with the weights proportional to the technological proximity, and finds evidence of a positive effect of technologically close firms' R&D on the productivity of own R&D.

Verspagen (1997) points to the importance of intersectoral spillovers to argue that the magnitude of spillovers between firms is not necessarily related to their 'technological similarity'.
In our view, technological proximity is a better proxy for the absorptive capacity of firms than it is for the spillover between firms, certainly if voluntary spillovers are substantial.
Katsoulacos and Ulph (1998) propose a model in which complementarity of knowledge is an important parameter in the value of useful information sharing. If research discoveries of partners are perfect complements, which is most often assumed, progress will be optimal.
If partners' discoveries are perfect substitutes there is a total overlap and no useful information can be shared.

Rycroft and Kash (1999) argue that networks are very effective mechanisms for incorporating tacit (i.e. non-codified) knowledge. Co-operation therefore seems a somewhat neglected channel for knowledge spillovers. This can probably to a large extent be explained by the fact that most scholars define spillovers as externalities and thereby do not consider voluntary 'spillovers'.

We are well aware that innovative networks entail far more then R&D networking, as the former also relate to the commercial exploitation of the results of R&D activities, and innovation does not always imply R&D activities.
Rycroft and Kash (1999) rightly warn against the danger of a policy overemphasis on R&D.

Throughout this paper we use the terms co-operation and networking intertwined. It is obvious that firms that have no other co-operative agreement, apart from their involvement in a single FWP project, can questionably be regarded as network agents. Our focus will however be on those firms and sectors that actively and frequently co-operate and are assumed do so from a strategic appreciation of their partners' contribution to a relatively clearly defined collaboration.

3. Rationale for a public policy of promoting R&D co-operation

Llerena and Matt (1999) show that the rationale for a policy of promoting interfirm co-operation in R&D depends on the theoretical perspective of the policymaker.
If a market or transaction cost stance is adopted, co-operation is often regarded as an (unstable) exception to competition.
The FWPs of the EU (see section 4) have been set up as block exemptions- dictated by the specific nature of pre-competitive R&D- to the strict EU competition rules.
However, the European Commission also promotes the follow-up of participation in its FWP by near-market collaboration in EUREKA projects[5], and thereby somewhat bends its own competition rules.
The US policy towards R&D co-operation in the early 1980s also consisted, apart from changes to intellectual property rigths, in a relaxation of antitrust regulation. Similar concerns as in the EU about loss of international competitiveness vis-à-vis Japan urged US policymakers to judge research

[5] EUREKA is an intergovernmental initiative which was proposed by the French government in 1985 as an alternative to the American Star Wars programme. EUREKA aims at fostering co-operation between firms. It is not an EU mechanism although as a member the EU finances some large EUREKA projects mainly in the field of ICT like Jessi (microelectronics) and HDTV (high definition television).

partnerships no longer merely on their static collusive effects, but also on their dynamic benefits (Hagedoorn, Link and Vonortas, 2000 : pp. 580-81).

From a more evolutionary perspective, interfirm agreements are considered to be a powerful coordination mechanism to create and diffuse knowledge within a vast, complex and rapidly evolving technological space.
Where public policy, following the traditional perspective, is concerned with adjusting market failures, the latter perspective demands policymakers to consider evolutionary failures, related to learning processes, lock-in and negative externalities (Llerena and Matt, 1999 : pp.188-94).

The extensive game-theoretical research that followed from d'Aspremont and Jacquemin (1988) originated the view that co-operation at the R&D stage and competition at the subsequent production stage results in a social welfare optimum. Given the nature of R&D activities (non-excludability, uncertainty and inappropriability) market resource allocation will not be socially optimal. Policy can resolve this market failure through promoting co-operation, subsidies and intellectual property rights. These findings were seen as support of the EU FWPs and national policies of promoting R&D collaboration.

However, the theoretical support for such policies is not that straightforward.

Amir (2000) compares the models that followed the d'Aspremont-Jacquemin (AJ) publication to the model proposed by Kamien, Muller and Zang (1992). Amir argues that the AJ models conflict with the stylized fact that industry R&D levels are decreasing in the spillover rate. The KMZ models confirm this stylized fact and therefrom Amir concludes that the AJ model is not very valid, especially for large spillovers, i.e. precisely for those situations that in the AJ model justify policy support.

From the viewpoint of the strategic investment literature, R&D competition is more optimal than collaboration if spillovers are small, and when spillovers are large the private and social welfare optimum coincide and public subsidies will not elicit many additional R&D activities. Publicly subsidized programmes of R&D collaboration are in this case only appropriate if spillovers are asymmetric (i.e. if there is sufficient diversity between firms in research capabilities).
If spillovers are differentiated between voluntary and involuntary the welfare results, and hence the policy conclusions, are not as clear either (Llerena and Matt, 1999 : pp. 182-86).

Cassiman and Veugelers (1998) point out that the fact that firms could manage spillovers within and through R&D co-operation, has hardly been adressed empirically.
Cohen and Levinthal (1989), Nelson (1992) and Teece (1992) have argued that tacit knowledge does not, contrary to the idea of knowledge as a public good, spill over effortlessly. Co-operation may increase knowledge flows between partners and can allow partners to internalize spillovers. In most theoretical models spillovers are exogenous to the decision to co-operate or not. Cassiman and Veugelers (1998) review some of the models that do acknowledge that partners may voluntarily increase spillovers between them.
The model proposed by Katsoulacos and Ulph (1998), in which spillovers are endogenized, predicts that firms from different sectors will fully share information, even if no co-operative agreement is concluded. From the finding of Katsoulacos (1993) that most R&D co-operation in the FWPs were between firms in different sectors they conclude that the EU subsidies to share information probably had a low additionality effect. Contrary to the findings of Katsoulacos (1993) the spillovers that we have computed show a high degree of intrasectoral co-operation (see section 6).

Pérez-Castrillo and Sandonís (1996) show that the EU policy instrument of cost subsidies may be counterproductive for knowledge sharing and that patent subsidies could be more effective.

This argument seems extremely forceful, as combined with the point raised by Katsoulacos and Ulph (1998), this suggests that at present the EU RTD policy supports projects that would occur anyway and discourages projects that would induce significant disclosure of knowledge, and that not so much the policy rationale, but the policy focus and instrument are wrong.

Anyhow, irrespective of which theoretical perspective is endorsed, the magnitude and specificities of spillovers are crucial for the rationale of a public policy towards promoting R&D collaboration, and this matter is still open to empirical scrutiny.

4. EU policy towards promoting R&D co-operation

The successive Framework Programmes of the EU, covering the "shared cost" type of collaborative research, have made an important contribution to the development of scientific and technological cooperation in Europe. The EU involvement in R&D cooperation can be traced back as far as the Treaty of Rome – establishing the European Atomic Energy Community-, and the other multi-annual research programmes, carried out either through the Joint Research Centre (JRC) or through funding to organizations in member countries (Caloghirou & Vonortas, 2000). However, at the beginning of the 1980s concerns were raised that European firms were falling behind their American and Japanese counterparts in terms of innovation and world market shares, especially in IT. Therefore, the Community launched a first Programme (ESPRIT 1) in 1984 to strengthen the scientific and technological basis of European IT Industry. ESPRIT 1 served as a model for the creation of a more general ''umbrella typed'' programme, which was called the 1st Framework Programme. The Framework covered various Programmes in many technological areas, promoting cooperative research and technological development (RTD). The aim was to link up the diverse and complementary technical capabilities of companies, universities and research laboratories from different European countries in pursuit of common technological goals (European Commission, 1997, Peterson & Sharp 1998, Mollina 1996). The main RTD policy instrument of the Framework Programmes has been the "shared cost" contract research projects, referring to the support by the Commission of 50% of total costs of joint research for companies, and up to 100 % of marginal and additional costs for universities and research institutes. Four Framework Programmes have already been completed (1984-1987, 1984-1991, 1990-1994 and 1994-1998) and the fifth is currently running (1998-2002).

The rationale for cooperative R&D stems basically from competitiveness and market failure issues. However in Europe political and economic changes have transformed the scene. New members have already been included in the EU -and many more might be included soon-, and new countries have emerged. Although the basic policy rationales have not altered, they have been joined with the cohesion and employment rationales of supporting collaborative R&D. It has been argued that ''there may be a trade-off between competitiveness and cohesion which may decrease the effectiveness of the Framework Programmes for RTD'' (Caloghirou, Tsakanikas and Vonortas, 2000). The results of the FWPs have been rather mixed. On the one hand they have not yet shown a substantial impact on European competitiveness and trade performance. This could be partially explained by the fact that collaborative research has been undertaken under the ''pre-competitive'' label. Too often successful projects did not produce marketable results, either because ''they have been isolated from market and social considerations despite their technical excellence, or because the means by which they were to be exploited were not specified or even thought about at the earliest stages of work'' (PREST, 2000)[6]. On the other hand they have helped to keep Europe in the technological race.
But the most important effect is that the FWPs have gradually become the driving force behind the formation of dynamic networks beyond formal collaboration, since they bring together researchers from the best laboratories in European firms and give private firms the opportunity to benefit from a larger pool of resources than is available in a single nation. They have unquestionably fostered the emergence of closer linkages and the creation of a critical mass through networking. In addition, they

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[6] That is why in the Fifth Framework Programme one of the changes that are implemented, is the recognition of the need for economic and social acceptance of the technologies and other results that have been produced through funded research.

provide stable financial support; they lead to a reduction of competition among researchers and between researchers and industry and of course provide access to complementary skills, means and tools. (Vavakova, 1995; Lucchini 1998). The EU policy towards promoting networking has been materialized solely through the funding of these research consortia. The success of this policy instrument (at least at that level) has promted the EU to adopt some additional measures in this direction: The establishment of multiple transnational networks for technology transfer and disseminatiuon (CEC, 1994), has also become a significant policy instrument in the last years. In any case, EU funding of R&D collaboration between organizations from all over Europe still remains the major policy instrument towards the promotion of networking phenomena, with positive effects especially on SMEs (Caloghirou & Vonortas, 2000).

5. Data

The Laboratory of Industrial and Energy Economics (LIEE) at the National Technical University of Athens (NTUA) has developed a new, extensive databank (STEP TO RJVs)[7], which includes several databases with detailed information on collaborative R&D in Europe. The paper draws information from the EU-RJV database, which contains information on cross-national R&D collaboration established in Europe through the FWPs[8]. Two basic criteria for developing this database have been used. First, we have selected Programmes focusing mainly on industrial research and exclude those that simply provide support, (e.g disseminate information etc.) or represent other EU actions. The database includes 64 Programmes from all FWPs, including big and well-known programmes (ESPRIT, BRITE/EURAM, RACE, etc.) but also some other smaller programmes, through which R&D cooperation is also perfomed[9]. Second, (at the project level) we have selected only R&D consortia for which it was positively identified that they included at least one firm as participant[10] (excluding e.g cooperation between Universities).
The implementation of the above citeria resulted to a final inclusion of 9335 research consortia, covering an extensive period of 16 years, (Sep. 1983 – Dec. 1998). About 20499 organizations from 52 countries are responsible for 64476 participations in these research collaborations. However, the real value adding part of this database is the conjunction of this information with financial data on the firm-participants. Drawing on AMADEUS[11], we managed to identify almost 40% of the firms participating in these consortia. Therefore data for 2722 European firms were retrieved, including sectoral information (primary activity in NACE 1 and CSO classification) that will be used in our analysis.

[7] The database was constructed in the context of an EU funded TSER project entitled ''Science and Technology Policies Towards Research Joint Ventures'' (Record Control Number 39084)
[8] The primary source of information was CORDIS
[9] A complete list of the Programmes included in the database is shown in the Appendix 1.
[10] In cases where it was impossible (dute to the poor quality of information) to identify an organization as a firm, we prefered to exclude them from the database
[11] A commercially available database that contains longitudinal financial information for approximately 200.000 European Firms.

6. Estimating knowledge spillovers through R&D co-operation

The basic hypothesis, that was used to compute intra- and intersectoral knowledge flows, is that the number of co-operative links between firms is a proxy measure for the underlying knowledge flows.
This hypothesis supports the view that 'learning by networking' entails more then sharing of information (i.e. cofified knowledge). If the latter would be the only concern, the network position is, from an efficiency perspective, more important than the multiplicity of contacts.
Hagedoorn and Duysters (2000) forcefully argue that from a learning perspective, multiple contacts in interfirm networks will be more effective than pursuing non-redundant contacts, dictated by strict maximizing efficiency rules. Following an efficiency networking strategy, firms would favour bridge ties (non-redundant links, overarching structural holes, to central network agents) to multiple and possibly redundant linkages.
Hagedoorn and Duysters, however, find evidence that in a dynamic environment (in casu the international computer industry) the absolute number of network links is more relevant than network status (Hagedoorn and Duysters, 2000: p. 23).

We constructed an asymmetric matrix. The asymmetry results from the hypothesis that in R&D projects more knowledge flows from the partners to the prime contractor than the other way round, whereas knowledge flows between 'normal' partners are assumed to be balanced. The results of a survey on the impact of the fourth FWP in Finland, show that project coordinators more often than other participants assesed a project as successful (Luukkonen and Hälikkä, 2000: p.52). Coordinators have a central position in the project which, amplified by greater research capacities, probably allows them to gather and absorb more knowledge from the other participants than the other way about. Moreover the prime contractor is likely to have more contacts with its partners then the partners mutually, and hence, to have more learning benefits.

Box 1: Mathematical definition of spillovers

Spillover from sector J (all countries) to sector I in country C:

$$\mathbf{SP_{cij} = \Sigma_n \Sigma_k \Sigma_{l\neq k} (D_{pc})/NP_n [(P_{nk} \in C \text{ AND } P_{nk} \in I \text{ AND } P_{nl} \in J) \Rightarrow 1;0]}$$

C: country I, J: sector
n: project number
$k,l = 1... NP_n$

NP_n: Number of particpants in project n
$D_{pc} = 2$ if P_{nk} is prime contractor and 1 if not
$P_{nk:}$ k-th participant in project n

Spillover weighed by domestic sector I's R&D stock and all countries sector J's R&D stock:

$$\mathbf{SPRD_{cij} = SP_{cij} *(RD_{ci}*\Sigma_m (RCP_{cm}*RD_{mj}))}$$

RD_{ci}: R&D stock of sector i in country c
m = 1 … number of countries
RCP_{cm}: Revealed Comparative Preference (country c-country m)

A last assumption concerns the issue of 'intimacy'. As in smaller consortia the knowledge that can be exchanged , compared to larger and more interspersed ones, is supposed to be of a greater amount we assumed knowledge flows to be inversely related to the total number of participants in each project or agreement.

The spillover measures that were computed are summarized in box1.

To limit the analysis to the most significant sectors, we computed the matrix for the 25 most active sectors in terms of participation. This results in matrices with 625 cell values.

From these matrices we computed other matrices in which we weighed the spillover values.
First , following Cohen and Levinthal (1989), we considered that own R&D activities are important to absorb R&D that spills over. We therefore constructed national sectoral R&D stocks[12] from the OECD ANBERD database and we used the average over the period 1985-95 as a measure of the absorptive capacity of a given sector.

The second weight concerns the spillover pool.

We used the national sectoral R&D stocks to construct international sectoral R&D pools.
We have used the bilateral measures of Revealed Comparative Preference (RCP), defined in Dumont and Meeusen (2000) and used in OECD (1999 b), as weights for constructing this international R&D pool.

The RCP gives an indication of the relative preference of organizations of a country to co-operate with partners from a given other country.
So, similar to Katsoulacos and Ulph (1998: p. 339), our spillovers are the product of a measure for the absorptive capacity with a measure of knowledge sharing.

On the basis of the matrices with weighed spillovers we derived clusters using cut-off criteria, similar to those Hauknes (1999) used to derive I/O-based clusters for Norway. A first cut-off (link strength) restricts the linkages on the basis of the fraction of the spillover from a sector to a given sector in the total spillover a given sector receives. The second cut-off (significant sectors) restricts the linkages on the basis of the fraction of spillover from a sector to a given sector in the total spillover for all sectors (Hauknes, 1999: pp.63-64).

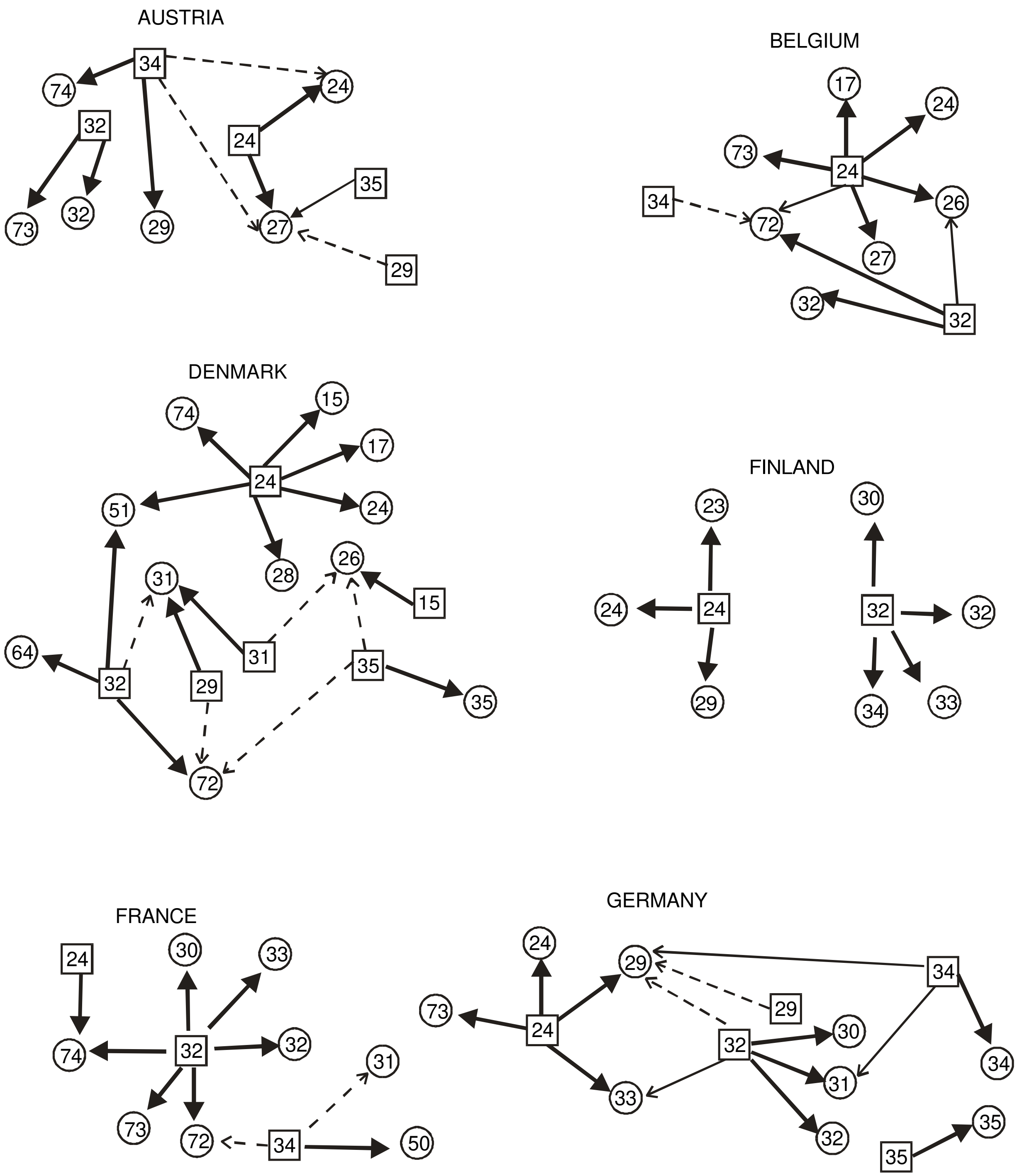
The clusters that result from this procedure are given in figure 1.

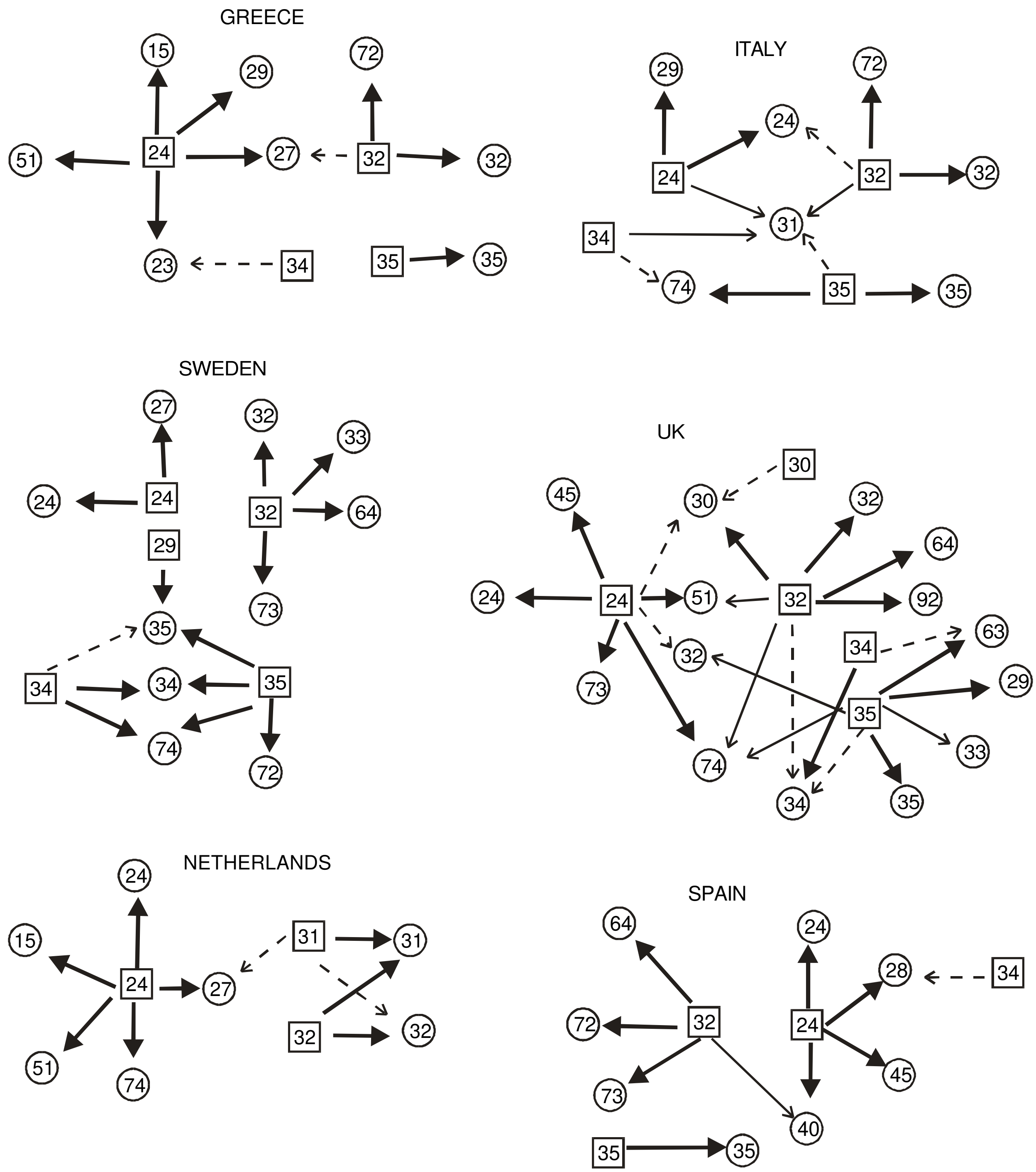
We represent three degrees of linkages. The strongest linkages represent intersectoral spillovers that are higher than 30 % of the total spillover flowing to the given (encircled sector in figure 1) sector and higher than 2 % of the total spillover for the given country. These are depicted by the thick arrows. The weaker linkages represent respectively fractions of 20 %-1% (normal arrow) and 10 %-0.5% (dashed line).

The technological domains (especially ICT) that the EC promotes through its FWP obviously influence the pattern of intra- and intersectoral co-operation. The mapping of more near-market collaboration (e.g. EUREKA) or of private alliances could preclude this bias[13].
The policy bias should however not be overstated, as the EC only fixes broad technological areas and is not concerned with specific sectoral patterns and as, moreover, it is precisely the network pattern that follows from the EU policy that we want to map.

[12] R&D stocks were computed following the formula given in Coe and Helpman (1995).
[13] Data on EUREKA collaboration are also available from the EU-RJV database and could be used in future research. There are also some datasources on private R&D alliances available (e.g. Merit-Cati).

Figure 1: FWP clusters on the basis of weighed spillovers (NACE 2 digit)





Supplier sector (all countries)

User sector (country)

$SP_{ij} >= 30\ \%$ of SP_i AND $SP_{ij} >= 0.02*\Sigma_j SP_j$

$SP_{ij} >= 20\ \%$ of SP_i AND $SP_{ij} >= 0.01*\Sigma_j SP_j$

$SP_{ij} >= 10\ \%$ of SP_i AND $SP_{ij} >= 0.005*\Sigma_j SP_j$

By multiplying two R&D stocks we may overestimate knowledge spillovers of R&D intensive sectors, and underestimate spillovers to low-tech industries. Some way of normalizing the R&D stocks could be considered.
R&D intensive sectors that are active in EC-pet technological areas are present in all clusters (i.e. *chemicals* (NACE 24) and *electronic equipment and components* (NACE 32)).
The clusters are probably not very revealing from this perspective.
Even at the two-digit level it can be seen that the clusters show some connection to I/O linkages but that they cannot simply be reduced to an I/O pattern.
There are important differences between countries as to the sectors that benefit from such knowledge spillovers.

Figure 1 shows that the clusters are more country specific with regard to user sectors than with regard to supplier industries. Moreover, some low-tech industries like *food and beverages* (NACE 15), *textiles (*NACE 17) and *iron, steel and non-ferrous metals* (NACE 27) appear in a number of clusters.
Both the weighed and unweighed spillover measures clearly show that in the FWPs co-operation within the same sector is important, although the two-digit level is too aggregated to conclude from this that there is a high degree of co-operation between direct competitors.

For a more disaggregated analysis we also computed matrices at the 3 digit level.
Unfortunately, no information on the sector of primary activity is available at the NACE three digit level.
Therefore we used the CSO three digit level.
We computed matrices of the 40 most active supplier sectors (all countries aggregated) and the 40 most active user sectors (given country), resulting in 1600 cells-matrices.

From these matrices we derived 3 digit clusters with similar but less strict clustering criteria[14] as for the 2 digit matrices. As no data is available of R&D stocks at the CSO 3 digit level the clusters are derived from unweighed spillover matrices. The clusters are shown in figure 2.

Figure 2 clearly shows the high degree of intra-sectoral co-operation within the FWPs.

As it concerns 'pre-competitive' collaboration, this finding should not immoderately warn us against collusion. The collaboration between competitors at the R&D stage can, as shown theoretically, result in a welfare optimum when followed by competition at the production stage and could also induce beneficial standard setting (see for the latter Rycroft and Kash, 1999: p.4). However, policymakers should remain vigilant to the potential danger of subsidizing (non-additional) R&D activities that could result in collusive lock-in situations. Hagedoorn and Schakenraad (1991) claim that the FWPs may have reinforced the shift towards a more oligipolistic IT market in Europe.

One way of sifting this matter is to look at the private networking and market behaviour following after (and preceding) FWP collaboration (see Dumont and Meeusen 1999, 2000).

The high degree of intrasectoral spillovers conflicts with the finding by Katsoulacos (1993) that the largest part of FWP co-operation occured between firms of different sectors.
It is noteworthy that the degree of intrasectoral spillovers is significantly higher in larger countries than in small countries[15]. This can also be seen in figure 2.

Large countries like the UK, Italy and France have clusters that to a large extent consist of intrasectoral linkages whereas countries like Austria, Denmark and Finland have far more diversified clusters.

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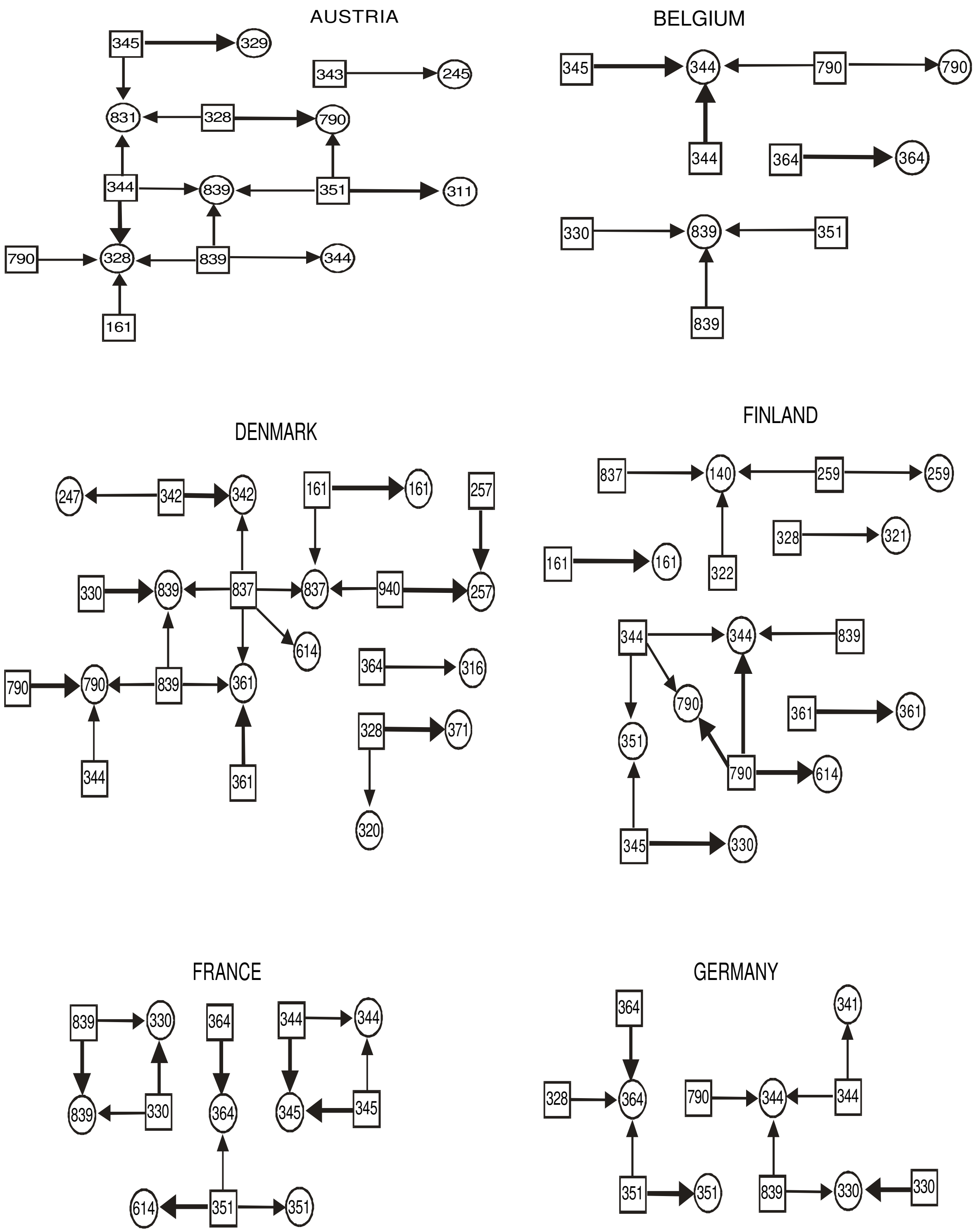
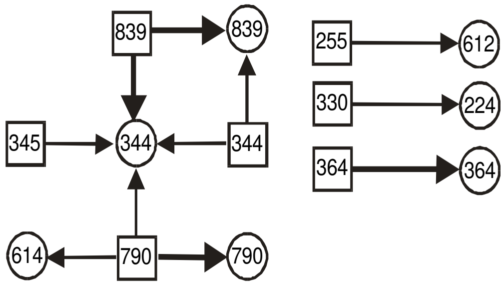
[14] 20 % of sectoral spillover and 1.5 % of total spillover for the strongest links (thick arrows) and 10 % of sectoral spillover and 1.0 % of total spillover for the weaker links (normal arrows).
[15] The correlation between country size and the degree of intrasectoral spillovers is 0.63, which is significant at the 5% level.

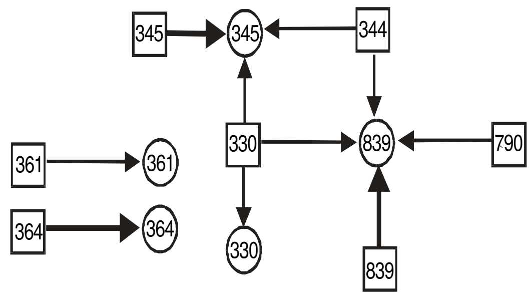
Figure 2: FWP clusters on the basis of unweighed spillovers (CSO 3 digit)



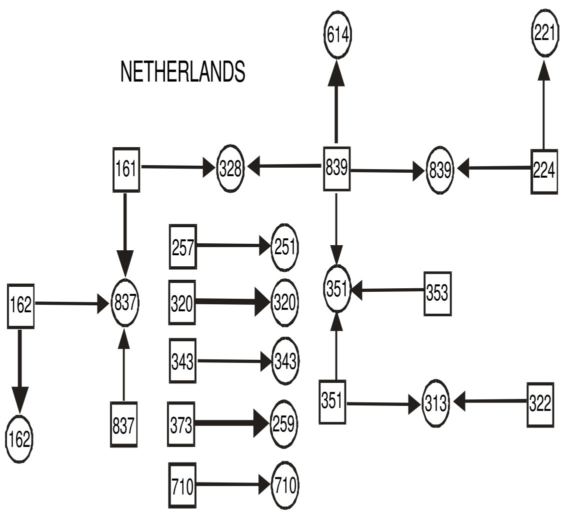
GREECE



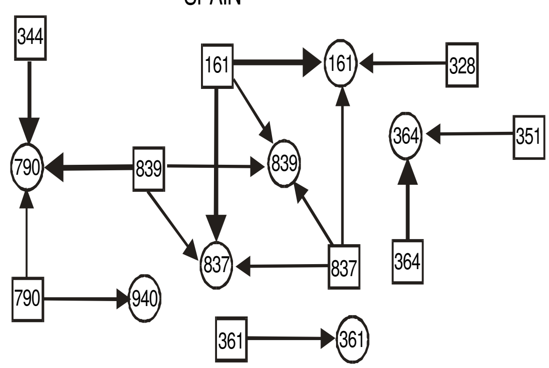
ITALY



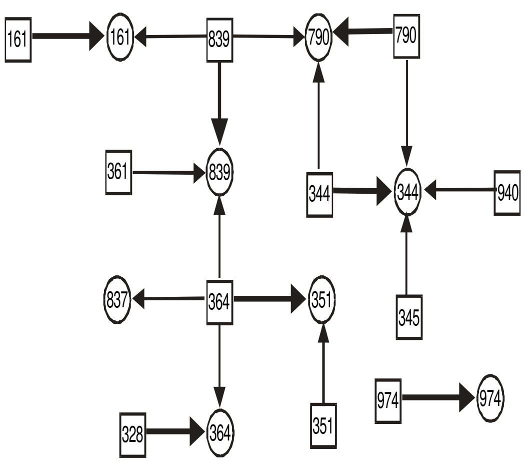
NETHERLANDS



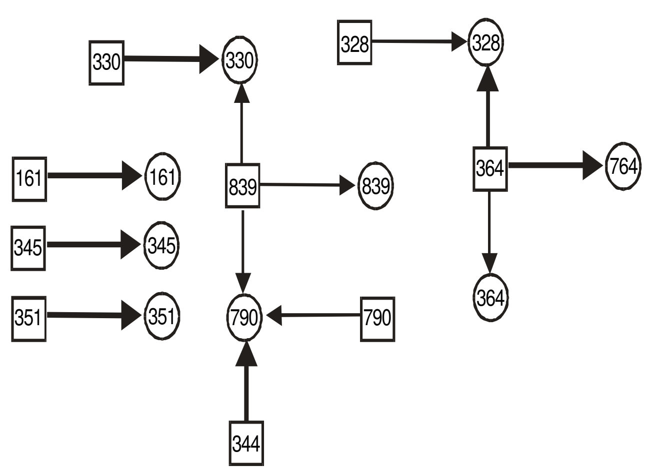
SPAIN



SWEDEN



UK



This finding could be explained by advisable standard setting and ‘pre-competitive’ co-operation between MNEs from large countries. However, keeping in mind the model of Pérez-Castrillo and Sandonís (1996), it could indicate that competitors self-righteously solve the moral hazard of knowledge sharing through collusive behaviour, and gratefully accept the presented financial support.

8. Conclusions

In this paper we used available data on subsidized R&D collaboration to compute knowledge spillovers between firms

The underlying motive is twofold.

From a methodological perspective, we argued that data on R&D collaboration may better comprise knowledge spillovers than methods based on Input-Output tables, as the latter focus on embodied or rent spillovers.

From a policy perspective, we indicated that the rationale of a public policy oriented towards promoting interfirm collaboration, irrespective of which theoretical perspective is endorsed, depends on the magnitude and specificities of spillovers, and that this matter is still open to empirical scrutiny.

The EU launched its ambitious Framework Programmes (FWPs), essentially to foster the catching up of EU firms to the US and Japan. The FWPs consisted in financial support for transnational collaboration between firms, higher education institutes (HEI) and research institutes (REC) in what was labelled as pre-competitive R&D projects, for which exemptions were issued on the strict EU competition rules.

Data on the FWPs, which are available from an official EU datasource, amplified with firm level data, were used to compute interfirm knowledge spillovers, assuming that the number of co-operative interfirm links is a proxy for the underlying knowledge flows.
We hereby endorse a learning perspective which, by focusing on ‘learning by networking’, assumes that multiple and possibly redundant co-operative links can be more effective than a strict efficiency perspective.

We constructed matrices for the 25 most co-operating sectors (NACE 2 digit).
We also constructed matrices of weighed spillovers, in which we considered the absorptive capacity and the spillover pool to be function of sectoral R&D stocks.
Using the matrices with weighed spillovers we derived clusters of the sectors with the highest spillover linkages.
Despite the rather strict cluster criteria, low-tech sectors like *food and beverages; textiles;* and *iron, steel and non-ferrous metals* were present in a number of country clusters. This might indicate that low-tech firms use the FWP to find partners that can compensate their lack of own R&D facilities.

Intrasectoral spillovers are found to be important. This conclusion holds when we look at the 3 digit level (CSO activity code) for which unweighed spillovers were computed.
If, given the ‘pre-competitive’ nature of the FWPs and the theoretical benefits of co-operation at the R&D stage, this finding should not necessarily be a warning sign of collusive behaviour, policymakers ought nevertheless to remain vigilant to promoting and subsidizing R&D activities with little additionality and/or a potential of creating collusive lock-in situations.
The latter seems even more obvious as there are indications that at least in the European IT market the FWPs may have reinforced a trend of gradual concentration.

The FWPs should, in our view, be embedded in a more general policy framework that deals, from a dynamic perspective, with all aspects of co-operation *and* competition and that acknowledges the importance of spillovers as a decision criterion for granting subsidies. Jaffe (1996) argues that policy support should favour projects with the highest spillover gap, which does not necessarily imply the highest spillovers. Although the FWPs promote networking, the focus up to now seems to have been on the R&D aspects of the projects and less on input and behavioural additionality, although the latter seems crucial from a 'learning by networking' perspective as it entails networking that would probably not occur without support. In his assessment of the Advanced Technology Program (ATP), which can be seen as the US counterpart of the EU FWPs, Jaffe gives the following advice which seems as relevant to the FWPs: " *Finally, to the extent that the policy justification for the ATP lies in creating spillovers, then any attempt to evaluate the ATP's success must try to measure those spillovers. Hence a better understanding of the process will foster the development of data collection and research efforts that are appropriate to quantification of the spillovers generated by the ATP investments*" (Jaffe, 1996: p.4).

The finding that the degree of intrasectoral spillovers is significantly higher in large countries than in smaller countries is remarkable and calls for further research.

If the matrices and clusters show some connection with I/O-tables it is also clear that the FWP linkages do not simply fit in the value added chain.

We think that the proposed method can complement other procedures of measuring spillovers and that this is interesting both for the empirical issue of measuring or estimating spillovers, as for the issue of the policy rationale for promoting co-operation, which to a great extent depends on the magnitude and nature of spillovers.

Further research could be oriented towards another initiative to promote collaboration in R&D. The Eureka program provides a useful counterbalance for examining whether incorporating more near-market projects affects the extent, magnitude and sectoral pattern of knowledge spillovers, compared to the 'pre-competitive' EU FWPs. In addition, analysing non-subsidized forms of collaboration (i.e. private alliances or strategic technological partnerships) could also provide interesting insights in the knowledge that is actually shared between partners in the absence of public intervention. The coincidence and chronological follow-up of linkages in the different types of co-operation (pre-competitive/ near-market/ market alliances) could also be helpful in establishing the outcome of network promoting policies, more particularly with regard to potential collusive behaviour.
As the FWP also promote the collaboration of firms with universities and research institutes we could analyse science-industry spillovers in a similar way as interfirm spillovers.
The spillovers should also be tested econometrically on their significance.

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APPENDIX 1

Programmes included in the RJV database.

Programme Acronym	FWP	Number of Projects	Budget (million ECUs)	Average funding per project	Criteria
ACTS	4th FWP	154	671	4,36	152
AERO 0C	2nd FWP	28	35	1,25	28
AERO 1C	3rd FWP	34	53	1,56	29
AGRIRES 3C	1st FWP	113	50	0,44	1
AIM 1	2nd FWP	43	20	0,47	36
AIM 2	3rd FWP	44	97	2,20	35
AIR	3rd FWP	436	377	0,86	184
BAP	1st FWP	366	75	0,20	69
BCR 4	2nd FWP	265	59,2	0,22	160
BIOMED 1	3rd FWP	274	151	0,55	3
BIOMED 2	4th FWP	674	374	0,55	146
BIOTECH 1	3rd FWP	156	186	1,19	33
BIOTECH 2	4th FWP	492	595,5	1,21	274
BRIDGE	2nd FWP	97	100	1,03	49
BRITE	1st FWP	219	185	0,84	206
BRITE/EURAM 1	2nd FWP	378	499,5	1,32	303
BRITE/EURAM 2	3rd FWP	472	770	1,63	388
BRITE/EURAM 3	4th FWP	2058	1833	0,89	1453
CAMAR	2nd FWP	80	55	0,69	21
CLIMAT 3C	1st FWP	108	17	0,16	0
CRAFT	3rd FWP	539	57	0,11	216
DECOM 2C	1st FWP	74	12,1	0,16	6
DECOM 3C	2nd FWP	73	31,5	0,43	31
DRIVE 1	2nd FWP	69	60	0,87	67
DRIVE 2	3rd FWP	66	124,4	1,88	59
ECLAIR	2nd FWP	42	80	1,90	41
ENNONUC 3C	1st FWP	789	175	0,22	136
ENS	3rd FWP	14	41,3	2,95	13
ENV 1C	3rd FWP	560	319	0,57	125
ENV 2C	4th FWP	715	914	1,28	222
EPOCH	2nd FWP	34	40	1,18	10
ESPRIT 1	1st FWP	241	750	3,11	234
ESPRIT 2	2nd FWP	435	1600	3,68	380
ESPRIT 3	3rd FWP	605	1532	2,53	483
ESPRIT 4	4th FWP	1599	2084	1,30	834
EURAM	1st FWP	87	30	0,34	62
EURET	2nd FWP	9	25	2,78	9
FAIR	4th FWP	632	739,5	1,17	240
FAR	2nd FWP	127	30	0,24	16
FLAIR	2nd FWP	34	25	0,74	17
FOREST	2nd FWP	38	12	0,32	14
HYMGEN C	2nd FWP	29	15	0,52	4
JOULE 1	2nd FWP	267	122	0,46	143
JOULE 2	3rd FWP	401	217	0,54	286
LIBRARIES	3rd FWP	51	22,5	0,44	35
LRE	3rd FWP	25	22,5	0,90	18
MAST 1	2nd FWP	48	50	1,04	48
MAST 2	3rd FWP	93	118	1,27	34
MAST 3	4th FWP	157	243	1,55	85
MAT	3rd FWP	178	67	0,38	57
MATREC C	2nd FWP	71	45	0,63	67
MHR 4C	2nd FWP	211	65	0,31	0
NNE-JOULE C	4th FWP	577			475
ORA	3rd FWP	19	14	0,74	16
RACE 1	2nd FWP	94	550	5,85	83
RACE 2	3rd FWP	123	554	4,50	118
RADWASTOM 3C	1st FWP	217	62	0,29	30
RADWASTOM 4C	2nd FWP	121	79,6	0,66	40
RAWMAT 3C	1st FWP	236	70	0,30	84
REWARD	2nd FWP	13	6	0,46	11
SMT	4th FWP	394	307	0,78	242
TELEMAN	2nd FWP	21	19	0,90	20
TELEMATICS 2C	4th FWP	641	913	1,42	431
TRANSPORT	4th FWP	336	263	0,78	223
Totals		**17596**	**18709,6**		**9335**

Source: Adapted from CORDIS, CD-ROM (1999 III).

APPENDIX 2 : NACE (revision 1) list of actictivities- primary code (2 digit)

NACE	
15	Food and beverages
17	Textiles
23	Cokes, refined petroleum products and nuclear fuel
24	Chemicals
26	Non-metallic mineral products
27	Basic metals
28	Fabricated metal products (except machinery and equipment)
29	Machinery and equipment n.e.c.
30	Office machinery and computers
31	Electrical machinery and apparatus n.e.c.
32	Radio, television and communication equipment and apparatus
33	Medical, precision and optical instruments; watches and clocks
34	Motor vehicles and trailers
35	Other transport equipment
45	Construction
50	Sale, repair and maintenace of motor vehicles
51	Wholesale trade (except motor vehicles)
64	Post and telecommunications
73	Research and development
74	Other business activities
92	Recreational, cultural and sporting activities

APPENDIX 3 : CSO list of actictivities- primary code (3 digit)

CSO	
140	Mineral Oil Processing
161	Production and distribution of electricity
162	Public Gas supply
221	Iron and Steel industry
224	Non-ferrous metals industry
245	Working of stone and other non-metallic minerals n.e.c.
247	Glass and glassware
251	Basic industrial chemicals
255	Paints, varnishes and printing ink
257	Pharmaceutical products
259	Specialised chemical products
311	Foundries
313	Bolts, nuts, …; springs; non precision chains; metals treatment
316	Hand tools and finished metal goods
320	Mechanical engineering
321	Agricultural machinery and tractors
322	Metal-working machine tools and engineers' tools
328	Other machinery and mechanical equipment
329	Ordnance, small arms and ammunition
330	Manufacture of office machinery and data processing equipment
341	Insulated wires and cables
342	Basic electrical equipment
343	Electrical equipment for industrial use; batteries; accumulators
344	Telecommunication equipment; electrical measuring equipment; electronic components
345	Other electronic equipment
351	Motor vehicles and engines
353	Motor vehicle parts
361	Shipbuilding and repairing
364	Aerospace equipment manufacturing and repairing
371	Measuring, checking and precision instruments
373	Optical precision instruments
612	Wholesale distribution of fuels, ores,metals and industrial materials
614	Wholesale distribution of machinery, industrial equipment and vehicles
710	Railways
764	Supporting services to air transport
790	Postal services and telecommunications
837	Professional and technical services n.e.c.
839	Business services
940	Research and development
974	Radio and television services

Source : Amadeus (2000)