The evolution of intra- and inter-sector knowledge spillovers in the EU Framework Programmes

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Abstract

In this paper we compute knowledge spillovers springing from R&D co-operation in the EU Framework Programmes.

Contrary to most other methods we estimate spillovers in a direct way, following a limited number of assumptions.

Intra- and inter-sector spillovers are computed for the first four FWPs, to analyse the evolution of the pattern of co-operation in response to policy and other (e.g. technology) shifts.

We endorse a 'learning by networking' perspective, which acknowledges that knowledge flows are not limited to flows of codified information and argue that measuring spillovers is essential in assessing the rationale and the impact of network-promoting policies.

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1. Introduction

Although, as can be learned from the burgeoning (game-)theoretical literature on spillovers and R&D co-operation, the magnitude and specific nature of spillovers is a crucial factor for the rationale of a policy to promote and subsidise R&D co-operation, there has been relatively little empirical investigation of spillovers in general, and spillovers within the EU Framework Programmes (FWPs) in specific.

In this paper we apply the method, proposed in Dumont and Tsakanikas (2001 a, b), to measure knowledge spillovers springing from co-operation in R&D.

Contrary to most other methods of measuring spillovers, we clearly define the spillover mechanism and estimate knowledge spillovers in a direct way, following a limited number of prior assumptions.

By focusing on spillovers through subsidised R&D co-operation within the EU FWPs we can assess the impact of a large-scale network promoting policy. As Jaffe (1998) argues in his assessment of the US Advanced Technology Program (ATP), evaluating a program of which the rationale is to create spillovers, implies an attempt to measure spillovers.

We use data on inter-firm linkages established within the EU Framework Programmes (FWPs) of subsidised cross-national 'pre-competitive' collaboration in R&D.

We compute intra- and inter-sector spillovers for each of the first four FWPs, to analyse the evolution of the pattern of co-operation in response to policy and other (e.g. technology) shifts.

We endorse a 'learning by networking' perspective, which acknowledges that knowledge flows are not limited to flows of codified information. Hence, redundant linkages can be justified, whereas an efficiency approach focusing on the flows of codified knowledge would favour a strategic network position with as few (redundant) linkages as possible.

2. Evolution of the EU FWP funding

In the beginning of the 80' concerns were raised that the EU economy was falling behind the US and Japan, especially in the area of ICT. The formation of a Programme promoting collaborative research in this specific area was the first action the EU took in order to face decreasing market shares in this sector. ESPRIT 1 was established in collaboration with 12 large European ICT firms in order to strengthen the scientific and technological basis. However, the official basis for the implementation of science and technology policy in the European Union was created only in 1987, when the legal enactment of the First Framework Programme was established in the Single European Act. ESPRIT 1 served as a model and spirited the creation of a general ''umbrella typed'' Framework which included programmes in other technological areas as well. The official basis has been modified since, under the 1993 Maastricht Treaty and also under the 1996 Amsterdam Treaty, giving the ''final'' shape to what we today call the EU RTD policy. Its implementation is carried out through three major mechanisms:

- Shared cost contract RTD projects
- Concerned actions
- Own research activities taking place in a network of European Research Centers: the Joint Research Centre (JRC)

The first two action mechanisms represent the so called ''indirect measures'', as it concerns organisations and researchers from all over Europe taking part, whereas the third action represents a more direct measure, since it refers to own research activities by the EU. However, the main RTD instrument is without a doubt the first one, which gathers the main part of EU funding. Its coordination is carried out through the Framework programmes. The shared cost contract research projects refer to the subsidising by the Commission of 50% of the total costs of joint research for companies, and up to 100 % of marginal and additional costs for universities and research institutes.

The Framework Programmes act as planning instruments, laying down budget allocations in the various technological areas.

Four Framework Programmes have already been completed (1984-1987, 1987-1991, 1990-1994 and 1994-1998) and the fifth is almost completed (1998-2002).

The budget allocations of the successive Framework Programmes reflect the shift in policy priorities, given to different research fields, of the European Commission.

The allocations over technological fields are the result of a consultation procedure involving the European Commission, the Council of Ministers, the European Parliament and the Economic and Social Committee.

In table 1 we show the breakdown of the budget (millions of ECU) over the main technological fields in the second, third and fourth FWP. Over the years there have been changes in the naming and the content of these fields, but the table results from an harmonisation carried out by the Commission (European Commission, 1997, p. 503)

<Insert table 1>

The focus in the first FWPs was very much on *information and communications technology* (ICT), since this was, as pointed out above, the area which seemed the most in need of support. Priority was also given to the (nuclear) energy sector in this Framework.

In the Second Framework Programme, the RTD budget increased, although it was less than 3% of total government spending in RTD in the Members States and just about 1% of all (public and private) RTD spending (Peterson and Sharp, 1998).

Information and communications technology has, from the second FWP onwards, always been the main technological field in terms of budget allocation, although due to a diversification of priorities its share in the total FWP budget decreased steadily from a peak of 45.6 % in the second FWP to 33.0 % in the fourth FWP, in spite of a continuous increase in the absolute budget allocation for ICT.

The focus within the ICT budget shifted from strengthening international competitiveness of European IT firms in the first FWPs to technological support for the development of ICT infrastructure, with an increased budget for telematics applications (European Commission, 1997, p. 506).

Energy recorded the sharpest decrease over the FWPs with a budget share dropping from almost 50 % in the first FWP to 21.9 % in the fourth FWP. However, due to the renewed interest in energy saving and the development of non-nuclear energy, its share increased considerably from the third to the fourth FWP.

Life Sciences witnessed the sharpest increase in budget share which, apart from the emergence of *biotechnology* as an important research field, also reflects the link with the policy of the Commission regarding *agriculture*, *health* and *nutrition*. The budget share of *environment* increased from 6.6 % in the second to 11.7 % in the fourth FWP. Moreover, the Commission claims that almost all FWP technological fields consider environmental aspects (e.g. encouraging environment-friendly technologies) (European Commission, 1997, p. 507).

In recent FWPs efforts are directed towards more international co-operation, dissemination and valorisation of the results of the projects, and human capital, training and mobility. The FWP objectives are fitted in a more general socio-economic policy framework, with e.g. attention to user-friendlyness of ICT and sustainable growth (European Commission, 1997, pp. 507-509). Furthermore, in the 4th Framework, efforts were made to link the EU RTD policy with regional development policies and to the general aim of socio-economic cohesion. Therefore, the objective of reducing the scientific and technological gap between members states gained priority.

3. 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)[1], 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[2]. Two basic criteria for developing this database have been used. First, we have selected programmes focusing mainly on industrial research and excluded those that simply provide support (e.g. disseminate information) or represent other EU actions. The database includes 64 Programmes from all FWPs, including large and well-known programmes (e.g. ESPRIT, BRITE/EURAM, RACE) but also some smaller programmes. At the project level we have only selected R&D consortia for which it was positively identified that they included at least one firm as participant[3] (excluding e.g co-operation between universities).

The implementation of the above citeria resulted in a final inclusion of 9335 research consortia, covering an extensive period of 16 years (1983–1998). 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 firm level data of the participants. Drawing on AMADEUS[4], we managed to identify almost 40% of the firms participating in these consortia. Therefore data for 2722 European firms were retrieved, including sector information (primary activity in NACE 2 digit) that will be used in the analysis.

A complete list of the number of projects, the budget and average funding per project of each programme that is included in the database is shown in appendix. The last column in the appendix shows the number of projects that meet the criteria (e.g. at least one industrial partner) that were used to construct the datafile. Projects in the field of ICT (e.g. ESPRIT, ACTS, RACE, ENS), by far, have the highest average budget per project.

In table 2 the different technological fields in the first and second FWP, the third FWP and the fourth FWP, respectively, are classified according to the total number of projects included in the database, on

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[1] 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).

[2] The primary source of information was CORDIS.

[3] In cases where it was impossible (due to the poor quality of information) to identify an organization as a firm, we prefered to exclude them from the database.

[4] A commercial database, provided by Bureau Van Dijk, that contains firm level data on the approximately 200.000 largest European Firms.

condition of meeting the criteria discussed above (i.e. primarily the condition that at least one firm should be involved in the project).

< insert table 2>

The table reflects the relative diversification of policy priorities over the FWPs. Despite a significant increase in the total number of projects in the field of *information processing* and *information systems* in the fourth FWP, this field dropped from a first place in the three first FWPs to fourth place in the fourth FWP. The number of projects in *aerospace technology* more than doubled in each new FWP and this field recorded the highest number of projects in the fourth FWP. *Materials technology* and *industrial manufacture* hold a relatively stable and strong position in terms of number of projects in all FWPs. For *Environmental protection* the number of projects tripled in each consecutive FWP and climbed from a 23rd position in the first and second FWP to a seventh position in the fourth FWP. *Biotechnology* witnessed a sharp increase in number of projects in the fourth FWP, after a considerably decline in the third FWP.

A number of programmes, in the fields of *biotechnology-biomedicine*, *environmental protection* and *energy*, promote relatively more fundamental research than others, and are thereby characterised by a high degree of co-operation between universities and research institutes, and a low involvement of industrial partners whereas programmes in the fields of *ICT*, *materials technology* and *industrial manufacture* cover more applied research and enjoy more interest from firms. There seems, however, to have been a significant twist over time in the relative involvement of industrial partners. Programmes like BIOMED, BIOTECH and ENV witnessed an increase in the percentage of total projects that are withheld whereas for programmes like ESPRIT and BRITE-EURAM this percentage decreased considerably. In table 3 the NACE sectors are classified by the number of project memberships in the FWPs at the EU level. The first five sectors in terms of memberships represent over 40 % of all memberships.

Transport sectors 34 and 35, *research & development* (73) and *post and telecommunications* (64) have the highest average number of memberships per firm. The strong position of sector 35 is explained by the large number of projects in *aerospace technology* (*manufacture of aircraft and spacecraft* is subsector 353).

<insert table 3>

4. The computation of spillovers within the FWPs

In this section we briefly describe the procedure that we use to compute spillovers springing from co-operation in the FWPs. For a more detailed discussion and the first application of this method we refer to Dumont and Tsakanikas (2001 a, b).

In Dumont and Tsakanikas (2001 a, b) we have argued that a public policy that would only draw conclusions from input/output-based methods, often used to analyse (embodied) spillovers, 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, and that such a policy may moreover run the risk of promoting inefficient and collusive lock-in situations.
As input/output-based methods are acknowledged to be rather unreliable for small, open economies (Debresson and Hu, 1999), and international spillovers are often found to be more significant for this type of countries, an approach that precludes the shortcomings of i/o-analysis seems even more to be called for, for these countries.

The method that we propose to estimate disembodied knowledge spillovers[5] focuses, in contrast to most other approaches, on a specific spillover mechanism that seems to have been somewhat neglected, i.e. co-operation in R&D. The reason of this neglect, despite the increasing co-operation in R&D, is probably that most scholars stick to the traditional strict definition of spillovers as externalities (e.g. Grossman and Helpman, 1992; Branstetter, 1998). Some recent definitions,

[5] Griliches (1992) makes a distinction between "embodied" and "disembodied" R&D spillovers. Spillovers are defined as "embodied" if they relate to the purchase of equipment, goods or services (cfr. rent spillovers). "Disembodied" spillovers, which Griliches assumes to be more important than "embodied" spillovers, are defined as ideas resulting from the research of one actor, used by another actor.

however, comprise the voluntary exchange of useful knowledge (e.g. Llerena and Matt, 1999; Rycroft and Kash 1999; De Bondt, 1999). If in co-operation between firms, the largest part of knowledge flows between partners can be regarded as intended, spillovers- sensu stricto- should be considered as an inevitable result of co-operation, as pointed out by Inkpen (1998). Interfirm collaboration in R&D can be seen as an agreement in which mutual spillovers are, if not intended, at least implicitly accepted.

In contrast to other methods of measuring disembodied spillovers (e.g. Jaffe 1986, 1989; Branstetter, 1998) we do not assume an unambiguous decreasing relationship between technological distance and spillovers. If technological proximity can clearly be seen as a good proxy measure for the absorptive capacity we consider, following Katsoulacos & Ulph (1998), the total spillover as the interaction of a knowledge flow component with a measure for absorptive capacity. Collaboration involving knowledge sharing between close competitors is for obvious reasons more problematic than between more distant partners. Moreover, as pointed out by Katsoulacos & Ulph (1998), research by (technologically) close competitors may involve a high degree of overlap and therefore a lower degree of useful knowledge transmission-intended or not- than research efforts by more complementary partners.

Our basic hypothesis is that the number of co-operative links between firms is a proxy measure for the underlying knowledge flows, and thus for the spillovers that spring from these flows, which are assumed to be proportionate to the knowledge flows.

Hagedoorn and Duysters (2000) forcefully argue that from a learning perspective, multiple contacts in inter-firm networks will be more effective than pursuing non-redundant contacts, dictated by strict maximising efficiency rules. They find strong evidence that, in a dynamic environment, the absolute number of network links is more relevant than the network position (Hagedoorn and Duysters, 2000: p. 23).

We furthermore assume that in R&D projects more knowledge flows from the partners to the prime contractor than the other way round. Knowledge flows between ‘normal’ partners are assumed to be balanced.

Finally, we assume knowledge flows to be inversely related to the total number of participants in each project, to account for the fact that knowledge exchange is swifter in small than in large projects.

In box1 we give the mathematical definition of the spillovers.

To limit the analysis to the most significant sectors, we compute the matrix for the 25 most active sectors (at EU level) in terms of participation (see table 3). This results in matrices with 625 cells.

<insert box 1>

In Dumont and Tsakanikas (2001 a) we used domestic and foreign sector R&D stocks, computed from data on R&D expenditures, to weight the spillovers.

Domestic sector R&D stocks were taken as a proxy for absorptive capacity and foreign intra- and inter-sector R&D stocks as a proxy of the amount of knowledge that can spill over.

Due to a lack of data on R&D expenditures for a number of countries and sectors we prefer to perform the analysis on unweighted spillovers, which seems the more justified as weighting does not seem to alter the results considerably.

On the basis of the matrices we derive clusters of the most important intra- and intersector spillovers, using cut-off criteria, similar to those Hauknes (1999) used to derive input/output-based clusters for Norway. The 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 that that 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).

We consider three degrees of linkages. The strongest linkages are those linkages, representing more than 30 % of the total spillover flowing from a supplier-sector (aggregated over all countries and depicted in a box in the figures) to the given country recipient-sector (encircled sectors in figures) and more 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).

As the number of projects increased considerably in each consecutive FWP there is a significant size difference. The first FWP represents 793 lines in our file, the second FWP 2122 lines, the third FWP 3374 and the fourth 5678 lines. To ensure some degree of comparability and to preclude a size bias we decided to merge the first and second FWP. This seems moreover justified as the major shift in policy priorities occurred from the third FWP onwards.

5. The pattern of intra- and inter-sector spillovers

In figure 1 we show the EU clusters of the strongest intra- and inter-sector spillover linkages in the three periods that were considered: FWP 1+2 (1984-91), FWP 3 (1990-94) and FWP 4 (1994-98).

<insert figure 1>

In agreement with the diversification of technological priorities after the second FWP the cluster of the third FWP is more diversified than the one emerging from co-operation in the first and second FWP.

However, this pattern seems to have slightly attenuated in the fourth FWP with a cluster consisting of less and weaker links.

The only lasting strong links over the FWPs are the intra-sector links of sector 32 (*radio, television and communication equipment*) and sector 35 (*transport equipment other than motor vehicles*).

The dominance of ICT, despite its decreased budget share, is revealed by the central position of sectors 30 (*office machinery and computers*), 31 (*electrical machinery*), 32, 64 *(post and telecommunications*) and 72.

Sector 32 holds the most central position in all three clusters, but is clearly on the receiving side. From the third FWP onwards the sector is only a strong knowledge supplier to firms within the same sector. The position of sectors 30 and 72 weakened over the FWPs with sector 30 dropping out of the fourth FWP cluster altogether.

The increasing importance of *transport* is reflected in the central position of transport sectors 34 and 35 in the most recent FWPs. The strong position of sector 35 is, as already mentioned before, easily explained by the importance of *aerospace technology*, as shown in table 2, the technological field with the highest number of projects in the fourth FWP.

With regard to the renewed interest in energy (saving), we find an intermediate strong intra-sector link of sector 40 (*electricity, gas, steam and water supply*) and a weak link of this sector with sector 74 (*other business activities*), both in the third and the fourth FWP.

In the fourth FWP a weak link between sector 24 (*chemicals*) and sector 73 *(research & development*) emerges. As can be seen in table 2, the number of projects in the field of *biotechnology* that meet the criterion of the involvement of at least one firm, increased considerably in the fourth FWP. This is due to an increase of the total number of projects but seems even more to be due to the increased involvement of firms.

A large number of small biotech firms relatively recently spun off from universities. These spin-offs are mainly classified in sector 73[6].

A number of 'low tech' sectors like 15 (*food and beverages*), 17 (*textiles*), 27 (*basic metals*) and 28 (*fabricated metal products*) appear in the clusters, but apparently all of their linkages are intra-sector.

[6] As the AMADEUS data do not provide a sector classification at a lower digit level than two, it is unfortunately not possible to distinguish the role of pharmaceutical firms (subsector 244) and thus the linkages of these firms with biotech firms, classified in sector 73.

Pre-competitive R&D collaboration is clearly not limited to 'high tech' sectors, but 'low tech' sectors do not seem to receive much knowledge, through the FWPs, from other sectors. Trusting in the participation in FWPs, throws some doubt on the Pavitt taxonomy. Pavitt (1984) classifies sectors in a number of categories. 'Low tech' sectors like *textiles* are classified as 'supplier dominated' and are considered to be highly dependent on external sources for technology and to perform little own R&D whereas 'high tech' sectors are defined as 'science based' and considered to perform much own R&D and to have close contacts with universities and research institutes. In Dumont and Tsakanikas (2001 b) 'low tech' sectors like *food and beverages* (Nace 15) and *textiles* (Nace 17) had already be found to co-operate relatively much with universities and research institutes whereas 'high-tech' sectors like *electronic equipment* (Nace 32) and *instruments* (Nace 33) co-operate relatively little.

The degree of intra-sector linkages slightly decreased from 27 % in the first and second FWP to 24 % in the fourth. The percentage of domestic intra-sector linkages increased from 22 % to 26 %. Firms have apparently become less reluctant to co-operate with domestic competitors over time. The convergence of both percentages over time may be an indication of European integration having blurred the distinction between domestic and foreign competitors.

Over all FWPs, firms were already more inclined to work with domestic competitors (22 % in the first period- 25 % in the third FWP and 26 % in the fourth FWP of all intra-sector spillovers) than with domestic firms outside the sector (respectively 22 %, 18 % and 22 % of all spillovers were domestic).

The analysis being performed at the two digit level, the degree of intra-sector collaboration seems relatively low. If collaboration in R&D is indeed an important spillover mechanism, this casts some doubt on the assumed relationship between spillovers and technological proximity, unless technological proximity, as a measure for absorptive capacity, outweighs the knowledge flow component of total spillovers. Kesteloot and Veugelers (1997) found that in private R&D alliances the search for complementarity is more important than technological relatedness.

Katsoulacos and Ulph (1998) point out that R&D subsidies to share information will probably elicit little additional information sharing between less close competitors as they would, at least from a theoretical viewpoint, be inclined to fully share information anyhow. From the establishment that most co-operation in the FWPs is between firms from different industries they conclude that the FWP subsidies probably do not result in much additional efforts and information sharing. We believe this claim to be too pessimistic as to the benefits of collaboration. It rests on the assumption that information sharing is independent of co-operation, i.e. firms can fully share information without co-operating. However, If the tacit component of knowledge is important, co-operation can in our view result in knowledge flows between partners that could never be attained between non-co-operating firms.

For all four FWPs combined, the degree of intra-sector spillovers was found to be positively and significantly linked to country size (GDP). A breakdown over the different FWPs reveals that this positive correlation applies to the first and second FWP but disappears over time. For the first and second FWP the correlation (0.59) is highly significant but for the third FWP the correlation (0.35) no longer is.

For the fourth FWP the correlation even turns, be it insignificantly, negative (-0.08).

This finding may be explained by the dominant position, in the first FWPs, of the so-called 'Big 12', the 12 largest European IT firms, almost all originating from large countries. In 1983 more than 70 per cent, and by 1986 still more than half of the ESPRIT budget (the largest IT programme at the time) was granted to these firms, which to a large extent co-operated with one another (Peterson, 1991; Sandholtz, 1992).

Another significant correlation that was established in Dumont and Tsakanikas (2001 a, b), however, seems to have intensified over the FWPs. The correlation between the percentage of links with domestic partners and country size for the three periods is respectively 0.63, 0.75 and again 0.75. This highly significant correlation suggests that international co-operation is important to small countries in allowing firms from these countries to co-operate with foreign partners, by lack of appropriate domestic partners. From this point of view the Framework Programmes, and EU integration, may have been extremely useful for firms from small countries to look for and to establish contacts with foreign firms with complementary capabilities, contacts that might never have been established without the instrument of the FWPs.

Countries with a large number of objective 1 regions like Greece, Ireland, Portugal and Spain have a small degree of domestic linkages and thus highly depend on foreign partners for collaboration..
This finding shows the increasing importance of the Framework Programmes for the participating firms located in the ''cohesion countries''. Sharp (1998) already pointed out the ''small but steady rise in the shares of cohesion countries in partnerships''. In European Commission (1997) the impact of the FWPs on cohesion within the EU is analysed in detail. There are indications that the FWPs succeed in joining European centers of excellence to lagging EU regions but that this is limited to a happy few (Ireland, Lisbon and Attiki) and often limited to a small number of universities and research centers without many spillovers to local firms (European Commission, 1997, pp. 379-398).

In figure 2, figure 3 and figure 4 we show the country clusters, respectively for the period of the first and the second FWP, the third FWP and the fourth FWP. From these national clusters we can see that the EU clusters from figure 1 conceal considerable differences between countries in the pattern of sector spillovers.

We will not discuss the country clusters in detail but will just comment on a number of aspects.

<insert figure2, figure 3 and figure 4>

In agreement with the diversification of policy priorities we find that the country clusters diversify over time. The high correlation of the degree of intra-sector spillovers with country size in the first two FWPs is corroborated by the clusters. Large countries like France, Germany and Italy have very intra-sector clusters in the first period. The diversification and the increasing number of inter-sector linkages in the third and fourth FWP supports the finding that the correlation ceased to be significant in the third and fourth FWP.

The clusters, however, also show that the significant correlation in the period 1984-1991 can not entirely be explained by the dominance of the large IT firms as the intra-sector aspect at that time extended to a large number of sectors.

The clusters reveal the policy priorities of the Commission and the shift over time, but as ICT projects still received over 30 % of the total budget in the fourth FWP, the dominant ICT linkages somewhat blur the evolution of the spillover pattern over the FWPs.

We therefore carry out a shift-share analysis, traditionally used to analyse the dynamics of export market shares (e.g. Fagerberg and Sollie, 1987), in which we consider the total spillover pool in a given FWP as a 'market'. For each country and each possible intra- or inter-sector spillover link we compute a 'market' share. The shift-share analysis consists in decomposing the change of the 'market' share (between the 1st + 2nd FWP and the third FWP and between the third and the fourth FWP respectively) in three effects: the *share effect* measures the extent to which the total change of the share can be explained by a change of the share, measured at a fixed share composition at the EU level, and can therefore be seen as a competitiveness measure[7], the *composition effect* measures the part of the total share explained by a change in the composition of the EU matrix, keeping the individual shares fixed. Finally, the *adaptation effect*, which is an interaction effect, reflects the part of the total change due to a move towards or away of links that become more or less important at the EU level.

The analysis allows to establish the degree to which the share of a given EU country in the 'market of FWP co-operation' increased or decreased and whether this can be explained by the competitiveness, the specialisation and the adaptability of intra- and inter-sector linkages.

In table 4 we list the 20 strongest intra- and inter-sector links (on a total of 625 possible links) in terms of their share in the total EU spillover pool. In the first and second FWP the top 20 linkages account for 41.7 % of all linkages. This decreased to 30.8 % in the third FWP to slightly increase again to 32.2 % in the fourth FWP which confirms the impression from the clusters in figure 1 that in terms of intra- and inter-sector co-operation the third FWP was more diversified than the first two FWPs and that the diversification slightly decreased in the fourth FWP.

<insert table 4>

Intra-sector spillovers of sector 35 overtook intra-sector spillovers of sector 32 in terms of importance in the fourth FWP.

The importance of *transport* is confirmed by the high number of linkages with either sector 34 or 35 in the top 20 and the appearance of their intra-sector linkages in the top 3 both in the third and fourth FWP.

Energy sector 40 holds a fifth position both in the third and the fourth FWP and somewhat surprisingly the 'low tech' sector 17 (*textiles*) is in sixth position in the third FWP. True enough, *textiles* drops from the top 20 in the fourth FWP.

In general the list confirms the dominance of ICT related linkages over all FWPs. There is an apparent shift from hardware and to a lesser extent also from software to ICT equipment, trusting that sector 30 (*office machinery and computers*) drops from a second place (intra-sector) in the first and second FWP to the 17 th position in the third FWP, to fall out the top 20 altogether in the fourth FWP. In the fourth FWP all linkages (intra and inter-sector) of sector 30 drop from the top 20 list. The total number of linkages of sector 72 in the top 20 decrease from 7 in the first period to 5 in the third FWP and to only 3 (two of which are with sector 32) in the fourth FWP. The number of linkages of sector 32 on the other hand decrease from 6 in the first period to 5 in the third FWP but increase to 7 in the fourth FWP.

This shift becomes even more apparent from table 5 which lists the 15 fastest growing linkages and the 15 fastest declining spillover linkages at the EU level, resulting from the shift-share analysis.

<insert table 5>

Sectors 30, 32 and 72 are the sharpest declining sectors, obviously as a result of the diversification of policy priorities, in the third FWP compared to the first and second FWP, but whereas sector 32 recovers in the fourth FWP, the position of sectors 30 and 72 further decline. The list reveals the sharp

[7] In our case, this means that we keep the weights of each intra- and inter-sector link in the EU matrix fixed at its begin of period value.

increase in the third and the fourth FWP of transport sectors 34, 35 and 63 (*supporting and auxiliary transport activities*) and energy sector 40 in the third FWP.

There is a sharp increase of intra-sector co-operation in sector 64 (*post and telecommunications*). This is the sector of former national (monopolist) telecom operators. The deregulation and liberalisation of the EU telecom market, which started in 1987 with the publication of the Green Paper on the development of the common market for telecommunications services and equipment, culminated in the liberalisation of basic voice telephony services in 1998. Many public operators have since been privatised and the sector witnessed a large number of mergers and acquisitions. Telecommunications has an increasing share in the ICT market (Dumont and Meeusen, 1999).

The sharp increase of the intra-sector links of 'low tech' sectors 17 (*textiles*) and 15 (*food and beverages*) in the third FWP is almost entirely undone by a proportionate decrease in the fourth FWP.

In table 6 we report the overall shift-share effects of individual EU countries.
Comparing the change of total shares between the third FWP and the period of the first two FWPs, shows that large countries like France, Germany and the UK witnessed the sharpest decline in their shares, to a large extent due to a negative share effect, and small countries like Austria, Denmark and Sweden witnessed the highest increase, again to a large extent explained by a (positive) share effect. In the fourth FWP large countries like Italy and Germany lost shares and small countries like Sweden, Finland and Austria gained shares.
The sharp gain in shares of the latter three countries should not come as a surprise, given that they only officially joined the EU in 1995 (i.e. in the period of the fourth FWP).

<insert table 6>

Somewhat more surprising is that we find a significant positive correlation of 0.51 between the growth of GDP per capita in the period 1992-96 on the one hand and total share growth between the first period (1984-91) and the third FWP (1990-94) on the other hand. This would indicate that the evolution of the participation of a country in the ‘pre-competitive’ FWPs is to some extent a leading indicator of future GDP per capita growth. Given the crudeness of this measure, we will not take the point as far as suggesting that this can be seen as evidence of a positive impact of FWP participation on economic growth, but this result seems interesting enough to go into this matter in future research.

In table 7 we list the top 5 of the most positive and the top 5 of the most negative total shift-share effects for individual EU countries. This list shows which intra- and inter-sector spillovers contributed most to the overall change of the share of a given country.

Belgium, Germany and Ireland are the only countries for which the share decreased over all FWPs, as table 6 shows. The constant market share analysis performed by Van Essen and Verspagen (1997) reveals that, of a group of 10 countries, Germany and Belgium witnessed the sharpest decline in their high-tech market shares in the period 1988-1994.

From table 7 we see that for Germany and Ireland this is to a large extent due to the tenacity of sector 30 which lost ground at the EU level. Ireland, as can also clearly be seen from the scanty country clusters, seems to have ensconced itself in ICT related industries which contributed to its decreased share in the EU spillover pool.

<insert table 7>

The share of Austria, Finland, Greece, the Netherlands, Spain and Sweden increased in all periods, due to strong positions in sectors 24, 32, 40 and 72.

7. Conclusions

In this paper we apply the method, proposed in Dumont and Tsakanikas (2001 a, b), of computing knowledge spillovers in inter-firm R&D co-operation, to analyse the changing pattern of intra- and inter-sector collaboration in the 'pre-competitive' Framework Programmes (FWPs) of the EU.

The evolution reflects the shift in policy priorities of the European Commission but also of technology shifts in the economic space.

Despite a diversification of technological fields, ICT remained the dominant area over all FWPs, with a budget share of still more than 30 % in the fourth FWP. A steady growth in the number of private interfim alliances in ICT has been reported (Hagedoorn, 1993), indicating a general trend in the linkages that have been established in the European area. In addition Santagelo (2000), following the technological overlap notion of Mowery et al. (1998) finds that such a factor is crucial for the formation of strategic technological partnerships among similar ICT companies. Therefore it is not suprising that sector 32 (*radio, television and communication equipment*) holds a central position as a knowledge receiver in all FWPs. The precompetitive nature of the Framework Programmes does not seem to affect the general picture obtained from other partnerships as well (Hagedoorn and Schakenraad, 1990)

Sectors 30 (*office machinery and computers*) and sector 72 (*computer and related services*) steadily lost ground, indicating a shift away from hardware and to a lesser extent from software to equipment.

Following the increased budget share of the field of *transport policy* sector 34 (*motor vehicles*) but especially sector 35 (*other transport equipment*) have become both strong knowledge suppliers and spillover recipients over time, and hold a central position in the spillover clusters of the most recent FWPs.

The intra-sector spillovers of sector 35 even surpassed the intra-sector spillovers of sector 32 in absolute importance in the fourth FWP.

Some ‘low tech’ (or “traditional”) industries like 15 (*food and beverages*), 17 (*textiles*), 27 (*basic metals*) and 28 (*fabricated metal products*) appear in the clusters of strong spillover links, but apparently all of these linkages are intra-sector, indicating that pre-competitive R&D collaboration is not restricted to ‘high tech’ sectors. These ‘low tech’ sectors, however, seem to be highly self-reliant and do not receive much knowledge, through the FWPs, from other sectors. This finding, as well as data on the degree of co-operation of sectors with universities and research institutes, suggests that the taxonomy of Pavitt (1984), which primarily classifies ‘low tech’ sectors as ‘supplier dominated’ and ‘high tech’ sectors as ‘science based’, does not plainly apply to co-operation in R&D, at least not to co-operation within the FWPs.

An analysis at the country level reveals the country specificity of the intra- and inter-sector pattern of co-operation. Firms from small countries significantly rely more on foreign partners than firms from large countries, which again reveals the importance of networking for small countries, to make up for the insufficient scale and the lack of appropriate domestic partners. This finding also applies to the so-called “cohesion countries”. Sharp (1998) already pointed out the ‘’small but steady rise in the shares of cohesion countries in partnerships’’. The data reported in European Commission (1997) show that EU centres of excellence have joined with partners from lagging countries but that this is often limited to a happy few regions and a small number of universities and research centres with little spillovers to local firms so far.

Apart from the linkages created and the spillover effect that takes place, firms need to develop proper absorptive capacity (Cohen and Levinrthal, 1990) in order to fully benefit from this effect. That is why further research with data at the firm level could link the ‘’external’’ knowledge transfer phenomenon, captured by the spillover flow component, with the ‘’internal’’ processes that each firm uses in order to absorb and use this knowledge.

We also find a surprisingly significant correlation between the total change of the share of a country in the total EU spillover pool over the period 1984-1994 and the growth of GDP per capita over the period 1992-1996, but the crudeness of this measure restrains us of drawing any other conclusion than that this matter certainly deserves further consideration.

We believe that the proposed method to measure knowledge spillovers, following a limited number of assumptions and focusing on a specific and important if not somewhat neglected spillover mechanism, can be useful in the empirical analysis of spillovers in general, and can, more specifically, be instrumental in the assessment of a public policy of which, at least implicitly, the creation of spillovers is an important rationale.

Future research will focus on the econometric validation of the estimated spillovers, at firm and sector level, and on the follow-up of 'pre-competitive' co-operation within the FWPs by more market-oriented co-operation to establish the impact of a public policy of promoting R&D collaboration on private spontaneous R&D networking.

Appendix : FWP 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).

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Table 1: FWP funding (Mecu) of different technological areas

	2nd FWP	3rd FWP	4th FWP
ICT	**2275 (45.6 %)**	**2491 (42.7 %)**	**3405 (33.0 %)**
Information technologies	1600	1517	1932
(Tele)communications	550	548	630
Other (e.g. telematics)	125	426	843
Energy	**1173 (23.5 %)**	**1052 (18.1 %)**	**2256 (21.9 %)**
Thermonuclear fusion	611	562	840
Nuclear fission	440	231	414
Non-nuclear energy	122	259	1002
Industrial and materials	**845 (16.9 %)**	**997 (17.1 %)**	**1995 (19.4 %)**
Life Sciences	**390 (8.3 %)**	**706 (13.5 %)**	**1572 (17.0 %)**
Agro-industry (incl. fishery)	190	373	684
Biotechnology	120	184	552
Biomedical/ Health	80	149	336
Environment	**311 (6.6 %)**	**581 (11.1 %)**	**1080 (11.7 %)**
Environment	261	464	852
Marine science	50	117	228
Total*	**4994 (100 %)**	**5827 (100 %)**	**10308 (100 %)**

Source : EC (1994 : pp. 214-6)   * Total of the main technological fields

Table 2: Number of projects in different technological FWP fields[8]

1st and 2nd FWP	Projects	Funding	3rd FWP	Projects	Funding	4th FWP	Projects	Funding
INFORMATION PROCESSING, INFORMATION SYSTEMS	800	2686,9	INFORMATION PROCESSING, INFORMATION SYSTEMS	812	2038,1	AEROSPACE TECHNOLOGY	1453	1293,2
ELECTRONICS, MICROELECTRONICS	717	2629,7	AEROSPACE TECHNOLOGY	633	701,4	INDUSTRIAL MANUFACTURE	1453	1293,2
MATERIALS TECHNOLOGY	669	623,8	INDUSTRIAL MANUFACTURE	604	656,2	MATERIALS TECHNOLOGY	1453	1293,2
INDUSTRIAL MANUFACTURE	607	602,7	MATERIALS TECHNOLOGY	604	656,2	INFORMATION PROCESSING, INFORMATION SYSTEMS	1417	2358,9
AEROSPACE TECHNOLOGY	331	435,0	ELECTRONICS, MICROELECTRONICS	601	1753,0	ELECTRONICS, MICROELECTRONICS	986	1746,9
RENEWABLE SOURCES OF ENERGY	279	95,7	ENERGY SAVING	286	154,4	TELECOMMUNICATIONS	583	1274,7
OTHER TECHNOLOGY	206	173,0	FOSSIL FUELS	286	154,4	ENVIRONMENTAL PROTECTION	581	747,5
TELECOMMUNICATIONS	186	560,8	RENEWABLE SOURCES OF ENERGY	286	154,4	AGRICULTURE	514	612,3
MEASUREMENT METHODS	177	47,8	TELECOMMUNICATIONS	276	784,5	SAFETY	445	458,1
BIOTECHNOLOGY	163	144,3	RESOURCES OF THE SEA, FISHERIES	218	201,4	EDUCATION, TRAINING	431	612,0
WASTE MANAGEMENT	162	72,5	AGRICULTURE	184	158,2	BIOTECHNOLOGY	420	411,8
REFERENCE MATERIALS	160	35,2	FOOD	184	158,2	RESOURCES OF THE SEA, FISHERIES	325	412,6
STANDARDS	160	35,2	ENVIRONMENTAL PROTECTION	159	114,4	MEASUREMENT METHODS	242	188,8
ENERGY SAVING	143	65,8	METEOROLOGY	125	71,3	REFERENCE MATERIALS	242	188,8
FOSSIL FUELS	143	65,8	SAFETY	125	71,3	STANDARDS	242	188,8
OTHER ENERGY TOPICS	136	29,9	STANDARDS	70	60,0	FOOD	240	280,8
RADIOACTIVE WASTE	107	49,4	TRANSPORT	59	110,9	TRANSPORT	223	173,9
AGRICULTURE	77	97,3	MEASUREMENT METHODS	57	21,7	METEOROLOGY	222	284,2
SAFETY	76	69,1	REFERENCE MATERIALS	57	21,7	MEDICINE, HEALTH	146	80,3
TRANSPORT	76	83,3	MEDICINE, HEALTH	38	78,7			
RESOURCES OF THE SEA, FISHERIES	64	53,8	BIOTECHNOLOGY	36	40,9			
NUCLEAR FISSION	57	32,3	REGIONAL DEVELOPMENT	16	11,8			
ENVIRONMENTAL PROTECTION	48	49,9						
MEDICINE, HEALTH	40	19,0						
FOOD	34	16,9						
METEOROLOGY	10	11,8						
LIFE SCIENCES	4	2,1						

Source: Adapted from Cordis CD-Rom (1999 III)

[8] As the Europen Commission classifies projects in two or three technological areas there is an unavoidable doublecounting which explains why the total number of projects in table 2 exceeds the total number of projects in appendix 1. This does not, however, change the quality of the information that can be derived from this table.

Table 3: EU sector distribution of FWP participation

NACE	Description	Number of memberships	%	Number of firms	%	Average number of memberships per firm
32	Radio, television and communication equipment and apparatus	1387	11,4	152	5,8	9,1
74	Other business activities	1133	9,3	261	10,0	4,3
72	Computer and related services	925	7,6	142	5,4	6,5
35	Other transport equipment	911	7,5	66	2,5	13,8
24	Chemicals	787	6,5	175	6,7	4,5
34	Motor vehicles and trailers	704	5,8	57	2,2	12,4
29	Machinery and equipment n.e.c.	679	5,6	231	8,9	2,9
30	Office machinery and computers	504	4,1	54	2,1	9,3
73	Research and development	499	4,1	38	1,5	13,1
33	Medical, precision and optical instruments; watches and clocks	482	4,0	139	5,3	3,5
51	Wholesale trade (except motor vehicles)	462	3,8	184	7,1	2,5
40	Electricity, gas, steam and water supply	434	3,6	57	2,2	7,6
31	Electrical machinery and apparatus n.e.c.	423	3,5	82	3,1	5,2
64	Post and telecommunications	414	3,4	33	1,3	12,5
27	Basic metals	295	2,4	109	4,2	2,7
28	Fabricated metal products (except machinery and equipment)	273	2,2	106	4,1	2,6
45	Construction	207	1,7	64	2,5	3,2
26	Non-metallic mineral products	161	1,3	75	2,9	2,1
15	Food and beverages	149	1,2	80	3,1	1,9
17	Textiles	140	1,1	68	2,6	2,1
50	Sale, repair and maintenace of motor vehicles	131	1,1	16	0,6	8,2
23	Cokes, refined petroleum products and nuclear fuel	124	1,0	23	0,9	5,4
60	Land transport	107	0,9	26	1,0	4,1
92	Recreational, cultural and sporting activities	91	0,7	22	0,8	4,1
63	Supporting and auxiliary transport activities	85	0,7	18	0,7	4,7
52	Retail trade	74	0,6	28	1,1	2,6
25	Manufacture of rubber and plastic products	71	0,6	41	1,6	1,7
11	Extraction of crude petroleum and natural gas	64	0,5	18	0,7	3,6
22	Publishing, printing, reproduction of recorded media	59	0,5	38	1,5	1,6
14	Other mining and quarrying	52	0,4	16	0,6	3,3
	Other	351	2,9	188	7,2	1,9
	Totals	**12178**	**100,00%**	**2607**	**100,00%**	**4,7**

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

Table 4: Top 20 of spillover linkages at EU level

		FWP12			FWP3			FWP4
32	**32**	0,066	**32**	**32**	0,040	**35**	**35**	0,058
30	**30**	0,050	**34**	**34**	0,037	**32**	**32**	0,048
35	**35**	0,045	**35**	**35**	0,035	**34**	**34**	0,023
72	**30**	0,024	**72**	**72**	0,019	**24**	**24**	0,020
30	**72**	0,023	**40**	**40**	0,014	**40**	**40**	0,016
64	**32**	0,019	**17**	**17**	0,014	**34**	**35**	0,014
34	**34**	0,019	**24**	**24**	0,013	**64**	**64**	0,014
72	**72**	0,019	**29**	**29**	0,012	**72**	**32**	0,012
32	**72**	0,017	**32**	**72**	0,012	**35**	**34**	0,012
72	**32**	0,017	**35**	**34**	0,011	**32**	**72**	0,012
32	**30**	0,016	**72**	**32**	0,011	**72**	**72**	0,011
32	**64**	0,016	**32**	**64**	0,011	**35**	**29**	0,010
30	**32**	0,015	**34**	**35**	0,011	**64**	**32**	0,010
74	**74**	0,013	**35**	**29**	0,010	**35**	**74**	0,009
64	**72**	0,011	**72**	**30**	0,010	**74**	**32**	0,009
24	**74**	0,010	**64**	**32**	0,010	**33**	**32**	0,009
72	**64**	0,010	**30**	**30**	0,010	**35**	**63**	0,009
29	**35**	0,009	**74**	**74**	0,010	**29**	**35**	0,009
28	**28**	0,009	**29**	**35**	0,009	**74**	**35**	0,009
35	**29**	0,009	**30**	**72**	0,009	**32**	**33**	0,008

Table 5: Top 15 fastest growing and fastest declining linkages at the EU level

			FWP3-FWP12			FWP4-FWP3
	34	**34**	0,0177	**35**	**35**	0,0235
	17	**17**	0,0140	**35**	**63**	0,0076
	40	**40**	0,0101	**32**	**32**	0,0075
	24	**24**	0,0073	**64**	**64**	0,0073
	35	**34**	0,0073	**63**	**35**	0,0068
	34	**35**	0,0069	**24**	**24**	0,0066
	31	**31**	0,0065	**60**	**60**	0,0056
+	**15**	**15**	0,0044	**24**	**73**	0,0046
	72	**51**	0,0042	**35**	**32**	0,0040
	40	**29**	0,0038	**32**	**35**	0,0037
	29	**40**	0,0037	**35**	**74**	0,0037
	34	**31**	0,0035	**73**	**24**	0,0036
	40	**74**	0,0034	**34**	**35**	0,0033
	29	**31**	0,0033	**74**	**35**	0,0031
	26	**26**	0,0032	**27**	**27**	0,0029
	30	**30**	-0,0403	**34**	**34**	-0,0137
	32	**32**	-0,0252	**17**	**17**	-0,0120
	72	**30**	-0,0143	**72**	**72**	-0,0089
	30	**72**	-0,0137	**30**	**30**	-0,0070
	32	**30**	-0,0107	**72**	**30**	-0,0061
	30	**32**	-0,0101	**30**	**72**	-0,0050
-	**35**	**35**	-0,0098	**29**	**29**	-0,0048
	64	**32**	-0,0093	**15**	**15**	-0,0044
	24	**74**	-0,0070	**31**	**31**	-0,0043
	28	**28**	-0,0065	**74**	**74**	-0,0035
	72	**32**	-0,0059	**73**	**32**	-0,0033
	64	**72**	-0,0056	**74**	**30**	-0,0030
	32	**72**	-0,0053	**34**	**32**	-0,0029
	32	**64**	-0,0051	**72**	**24**	-0,0029
	72	**64**	-0,0042	**28**	**74**	-0,0026

Table 6: Country shift-share effects

				FWP3-FWP12				FWP4-FWP3
	Share	Composition	Adaptation	Total	Share	Composition	Adaptation	Total
Austria	0,00713	0,00000	-0,00056	0,00765	0,01491	0,00000	-0,00374	0,01108
Belgium	0,01271	-0,00030	-0,01292	-0,00051	-0,00699	0,00000	0,00043	-0,00656
Denmark	0,01566	-0,00004	0,00133	0,01694	-0,00862	-0,00002	-0,00167	-0,01031
Finland	0,00097	-0,00001	-0,00022	0,00073	0,01352	0,00000	0,00114	0,01466
France	-0,02174	-0,00225	-0,03901	-0,06300	-0,00468	0,00015	0,01207	0,00754
Germany	-0,00661	-0,00106	0,00514	-0,00253	-0,01478	-0,00008	-0,00583	-0,02069
Greece	0,00310	-0,00005	-0,00162	0,00144	0,00257	0,00000	-0,00064	0,00193
Italy	0,02358	-0,00071	-0,02275	0,00013	-0,02932	-0,00004	-0,00343	-0,03278
Netherlands	-0,00023	-0,00003	0,00284	0,00258	0,00773	-0,00002	-0,00421	0,00350
Portugal	0,00260	0,00001	0,00227	0,00488	-0,00365	0,00000	-0,00120	-0,00485
Spain	0,00127	-0,00016	0,00146	0,00257	0,00680	0,00000	0,00009	0,00689
Sweden	0,00548	0,00004	0,00009	0,00561	0,01730	0,00000	0,00002	0,01732
UK	-0,04390	-0,00095	-0,00285	-0,04769	0,00528	-0,00009	0,00472	0,00992
Ireland	-0,00001	-0,00003	-0,00025	-0,00029	-0,00008	0,00000	-0,00035	-0,00044

Table 7: Top 5 of highest and lowest total shift-share effects at country level

	FWP123	FWP123	FWP34	FWP34		FWP123	FWP123	FWP34	FWP34		FWP123	FWP123	FWP34	FWP34		FWP123	FWP123	FWP34	FWP34
AT	34	29	32	32	**BE**	64	32	34	72	**DK**	31	31	35	35	**FI**	24	24	64	51
	32	73	33	32		51	32	35	35		29	31	64	64		45	24	24	24
+	32	32	72	32		51	72	27	27		40	40	24	24		29	40	24	23
	26	26	32	29		74	32	64	64		40	28	73	24		40	23	72	33
	32	74	40	32		31	29	31	32		29	26	74	35		74	23	64	64
	27	51	30	73		74	27	73	32		33	35	40	28		30	33	31	40
	33	51	29	45		30	32	51	32		24	28	40	40		51	33	74	27
-	34	51	32	74		45	72	30	72		35	33	31	31		72	33	40	23
	72	32	26	26		74	73	32	32		35	28	17	17		64	33	29	40
	34	74	32	73		34	72	17	17		30	72	29	31		32	34	45	24
FR	15	15	35	35	**DE**	34	34	35	35	**GR**	32	72	64	64	**IT**	40	29	35	35
	34	34	32	32		35	34	32	35		72	32	32	32		34	31	64	45
+	72	51	34	35		34	35	32	74		29	27	64	51		29	32	64	72
	34	35	63	35		40	40	50	34		72	72	40	72		35	29	24	24
	92	32	72	32		24	24	60	60		30	72	30	32		74	31	32	72
	72	30	74	74		74	24	35	34		72	33	35	72		64	72	17	24
	24	74	15	15		32	30	32	31		26	51	32	72		30	32	72	30
-	30	72	30	30		64	32	29	29		45	26	17	17		32	72	30	72
	32	32	72	30		72	30	17	17		24	27	72	72		32	32	32	32
	30	30	34	34		30	30	34	34		35	35	29	27		30	72	72	72
NL	40	74	24	24	**PT**	24	40	40	40	**ES**	40	40	74	74	**SE**	40	40	35	34
	51	74	34	34		32	64	26	45		29	40	74	72		32	32	34	34
+	27	74	27	28		64	64	74	29		40	74	32	72		72	64	45	74
	72	51	29	28		24	24	63	51		32	73	74	26		72	74	32	32
	31	31	72	74		24	51	72	40		34	35	33	28		35	35	35	72
	72	29	31	31		51	17	24	24		24	35	34	35		29	34	73	32
	29	28	40	29		30	33	64	64		72	64	64	64		74	34	27	29
-	45	74	17	17		72	33	32	64		64	64	30	40		35	34	64	32
	74	74	27	74		51	32	24	40		72	45	32	64		35	74	72	64
	28	28	28	74		45	24	24	51		32	64	40	40		34	34	40	40

Table 7: continued

	FWP123	FWP123	FWP34	FWP34		FWP123	FWP123	FWP34	FWP34
UK	24	24	35	63	**IE**	35	29	72	30
	34	34	35	35		51	74	72	72
+	72	72	34	63		34	72	64	72
	40	40	40	40		64	30	24	15
	40	24	74	29		30	72	74	63
	32	30	72	30		33	30	40	30
	32	64	30	30		40	30	74	30
-	72	64	32	92		74	30	34	72
	32	32	72	72		72	30	51	74
	30	30	34	34		30	30	35	29

Figure 1: EU clusters of the highest intra- and inter-sector spillovers in three FWP periods

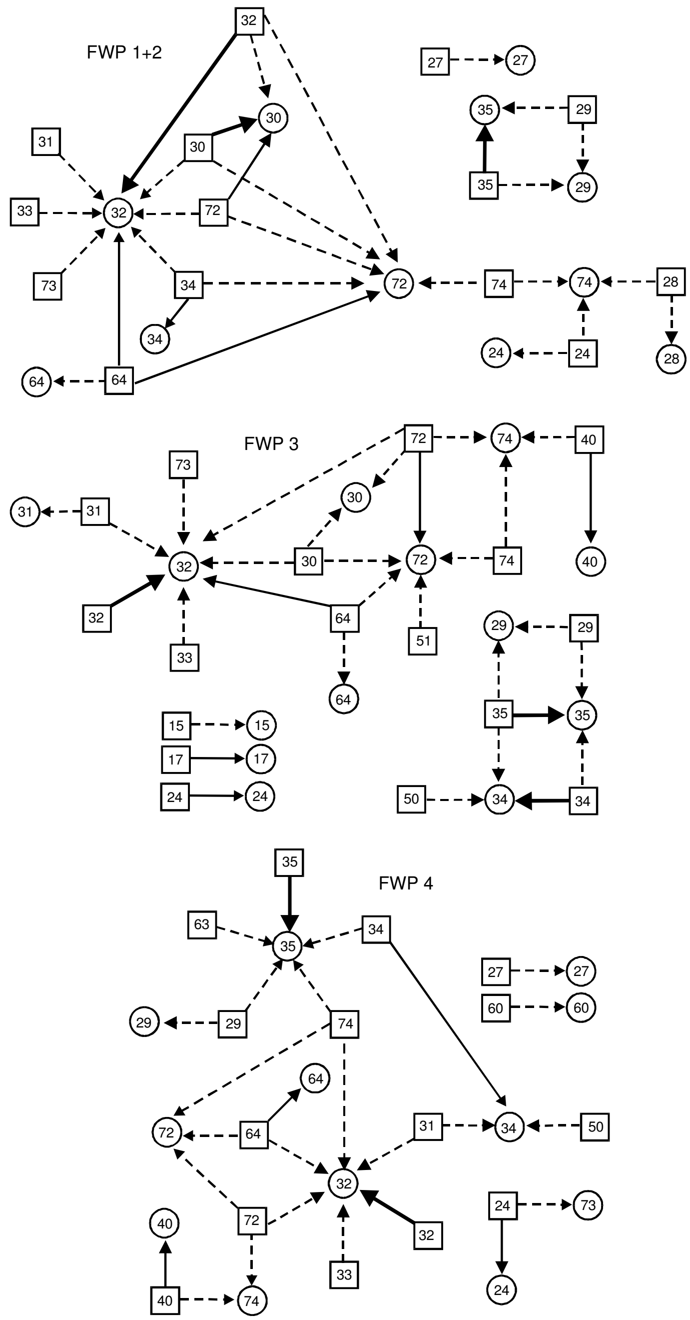
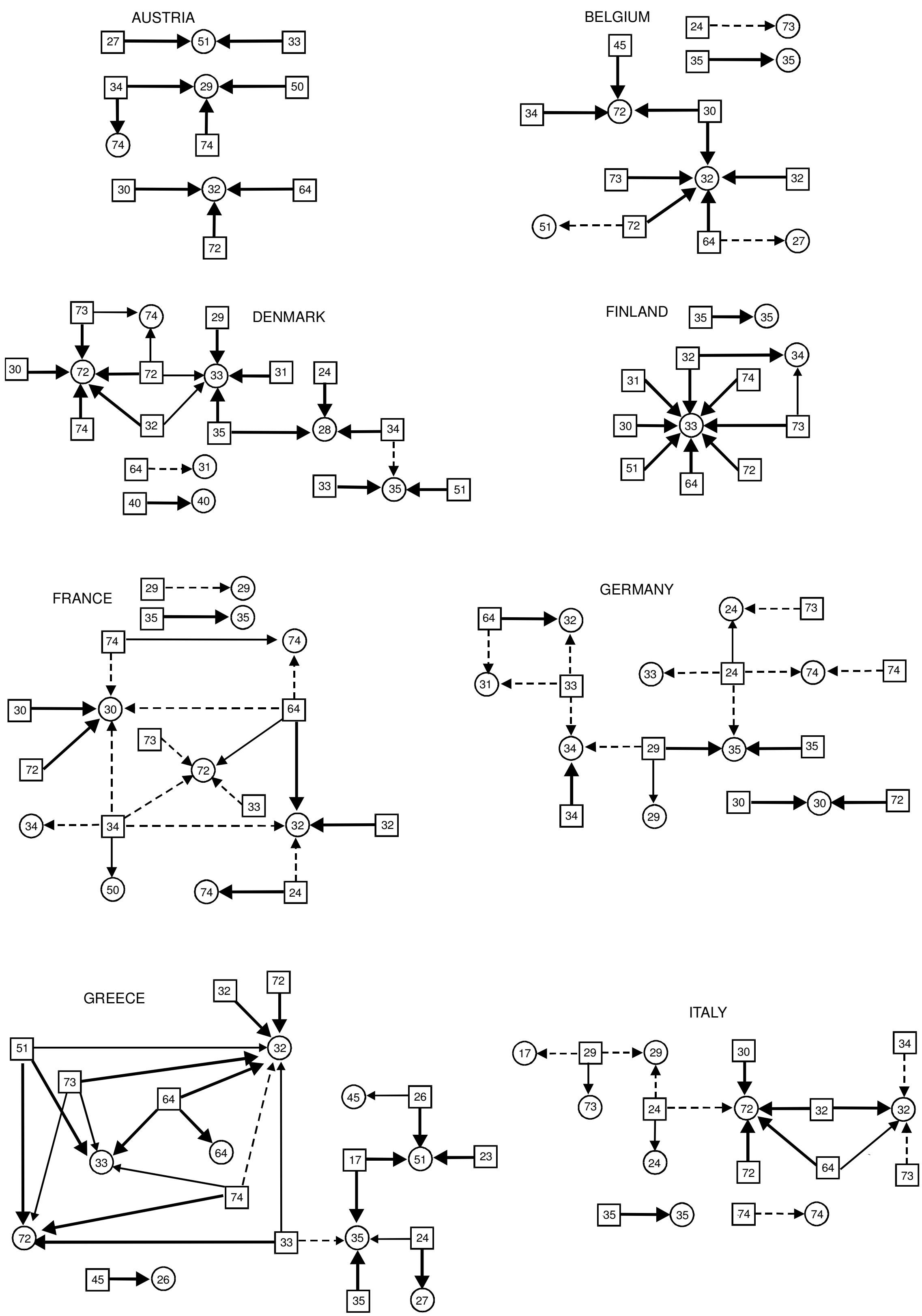
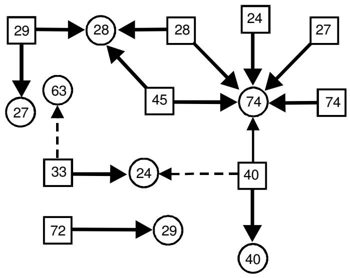


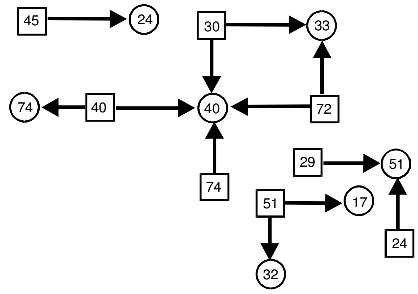
Figure 2: Country spillover clusters in the First and Second Framework Programme



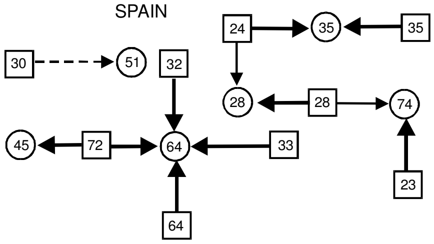
NETHERLANDS



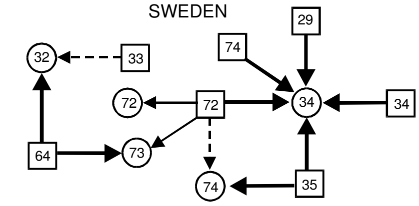
PORTUGAL



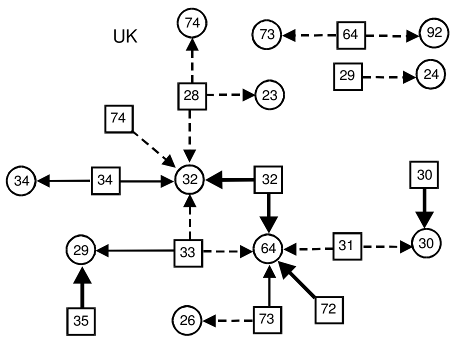
SPAIN



SWEDEN



UK



IRELAND

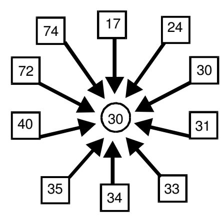
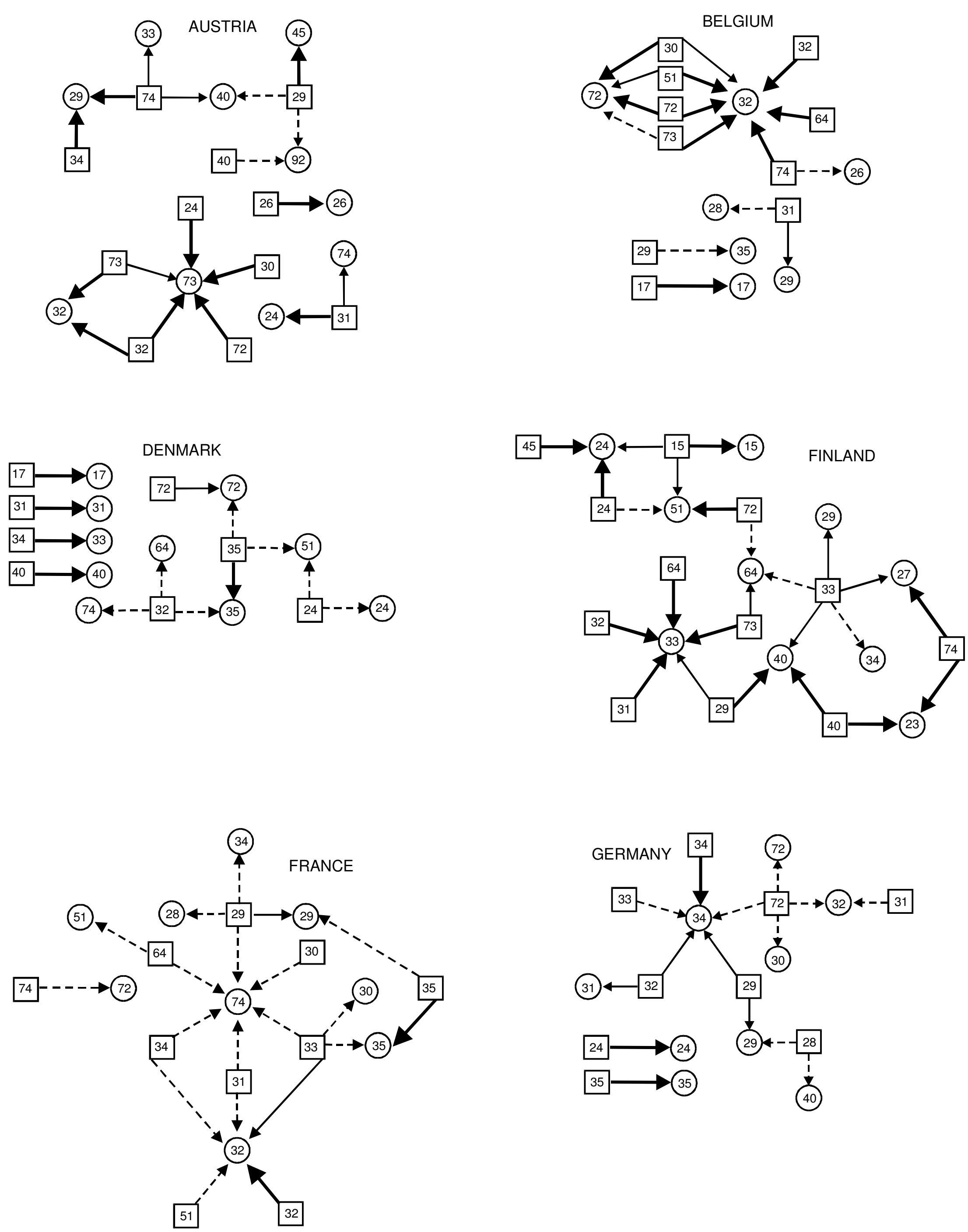
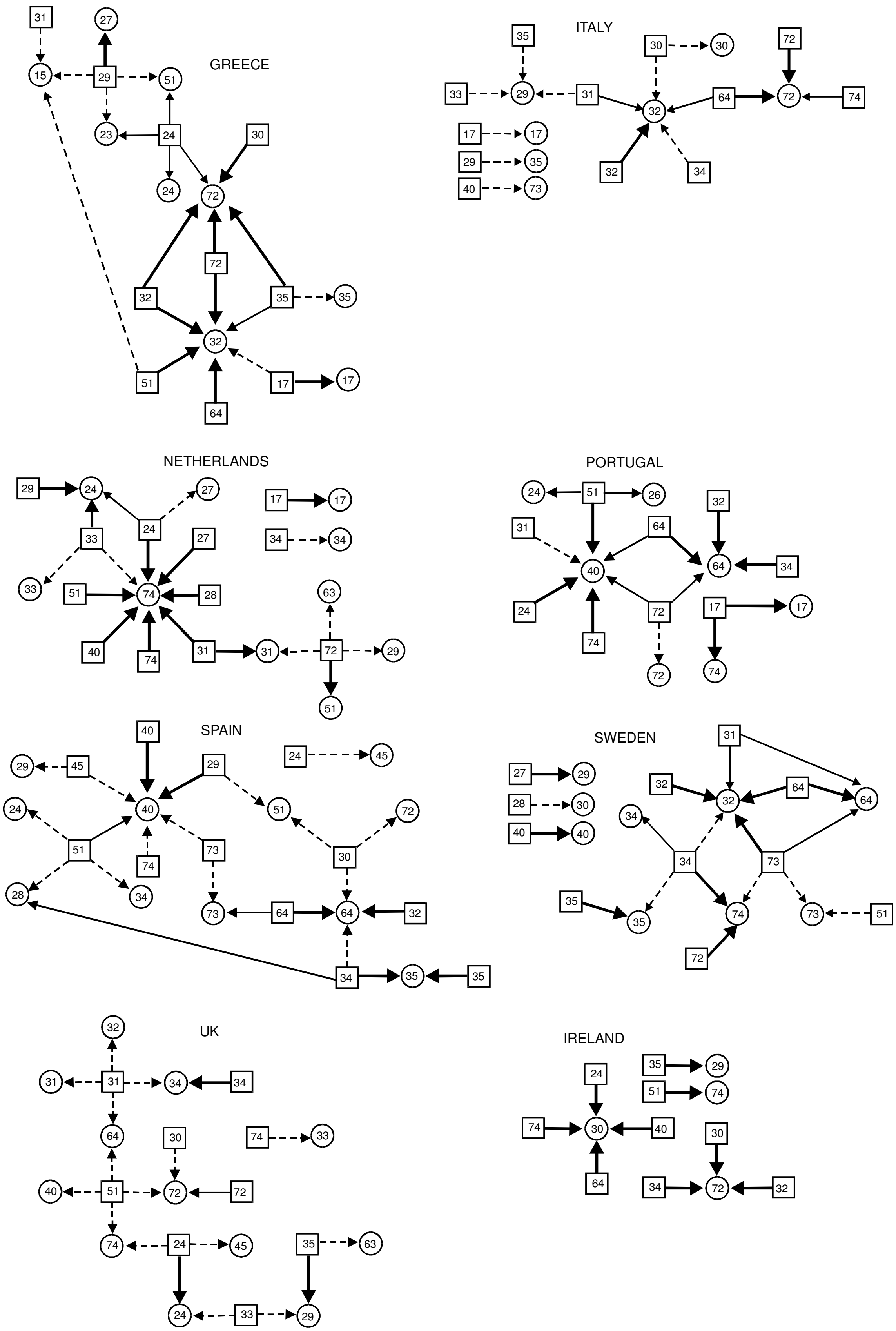


Figure 3: Country spillover clusters in the Third Framework Programme




GREECE
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ITALY
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NETHERLANDS
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PORTUGAL
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IRELAND
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64
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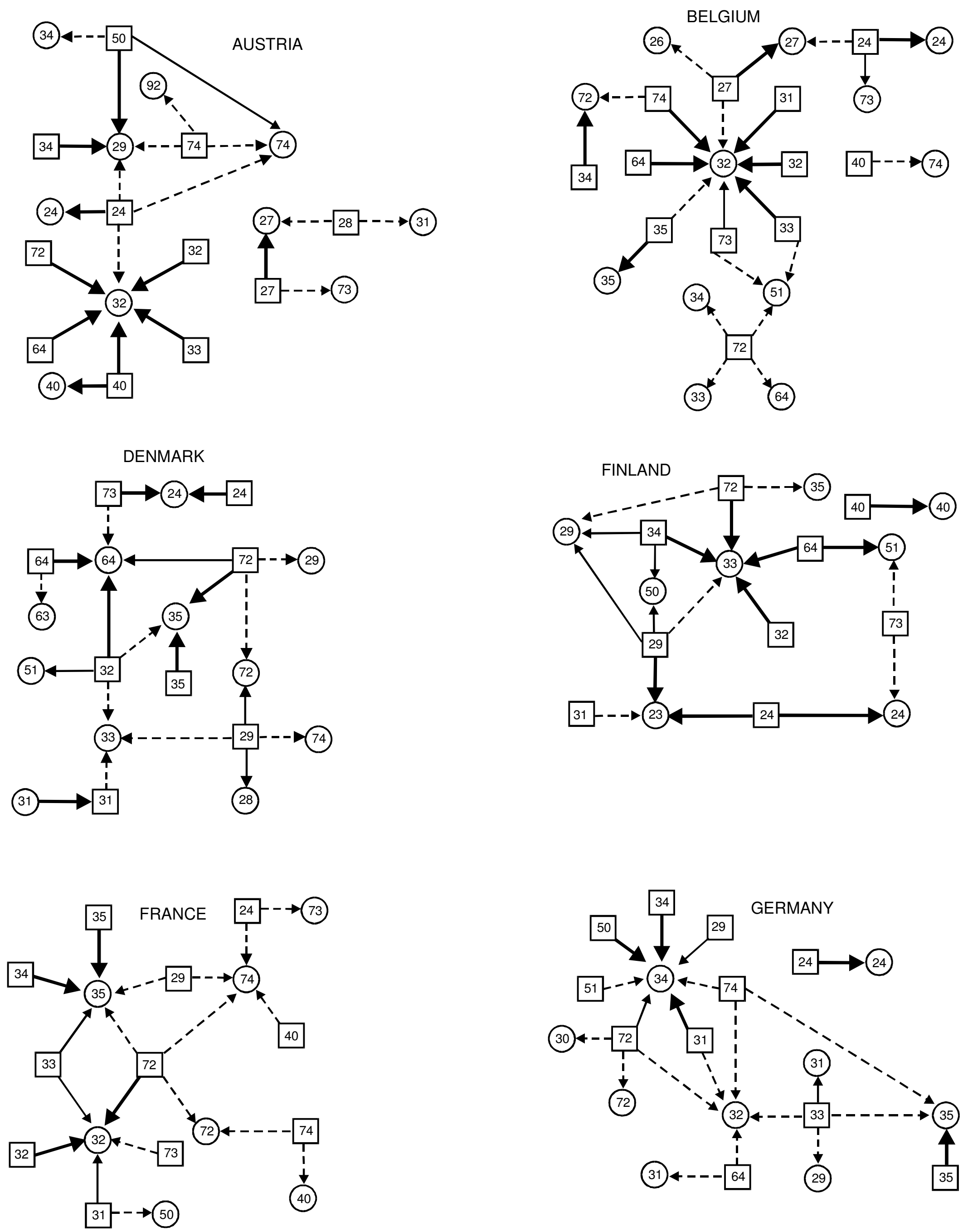
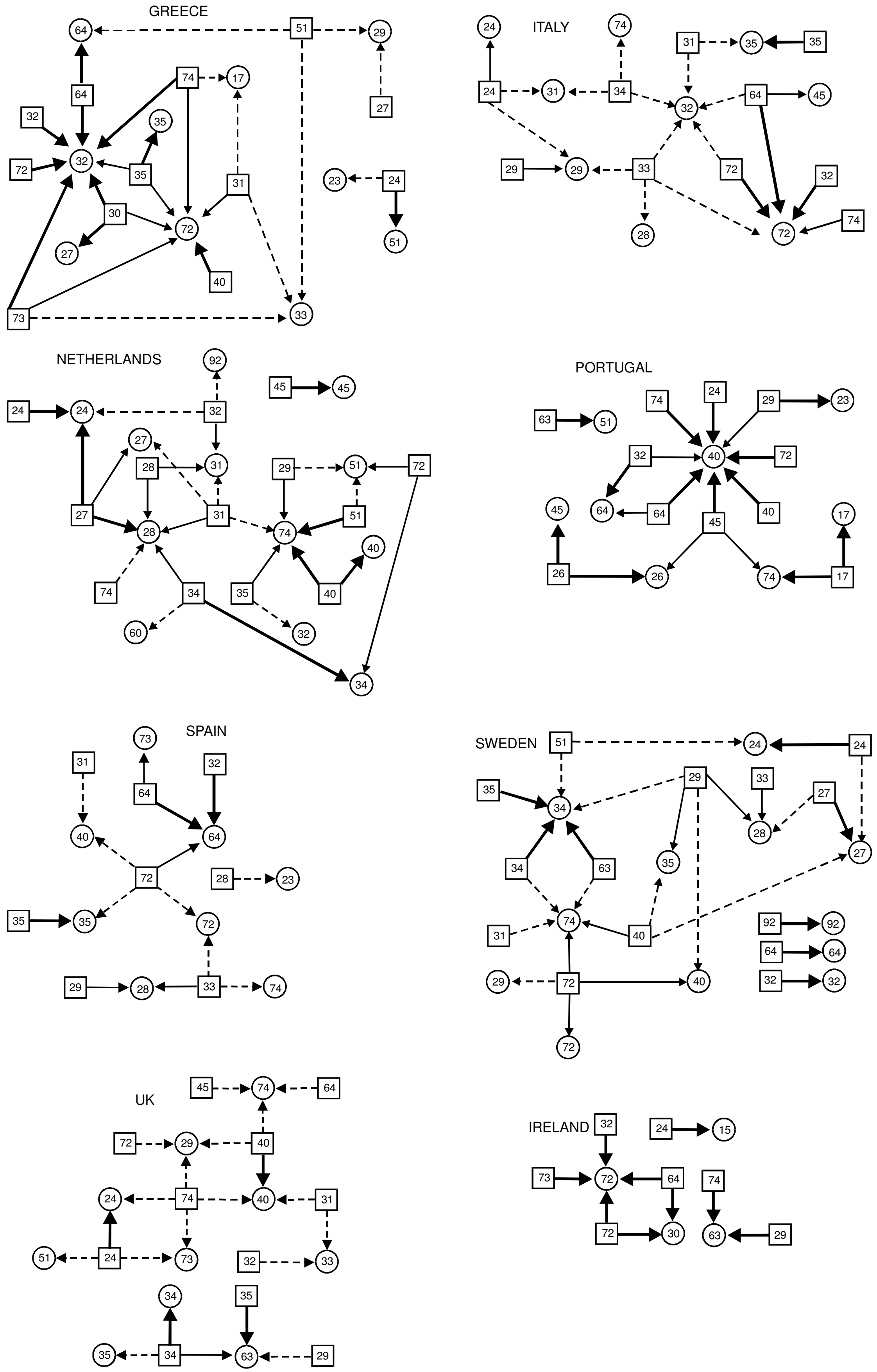
72
32

Figure 4: Country spillover clusters in the Fourth Framework Programme




GREECE
ITALY
NETHERLANDS
PORTUGAL
SPAIN
SWEDEN
UK
IRELAND