AQR workshop on Innovation and economic regional performace

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Does intentional mean hierarchical?

Knowledge flows and innovative performance of European regions

UNIVERSITÀ CATTOLICA del Sacro Cuore

M.A. Maggioni*°, M. Nosvelli*˛, T.E. Uberti*°

CSCC

***CSCC**

(**C**ognitive **S**cience and **C**ommunication research **C**entre)

°DISEIS

(Dept. of International Economics, Institutions and Development)

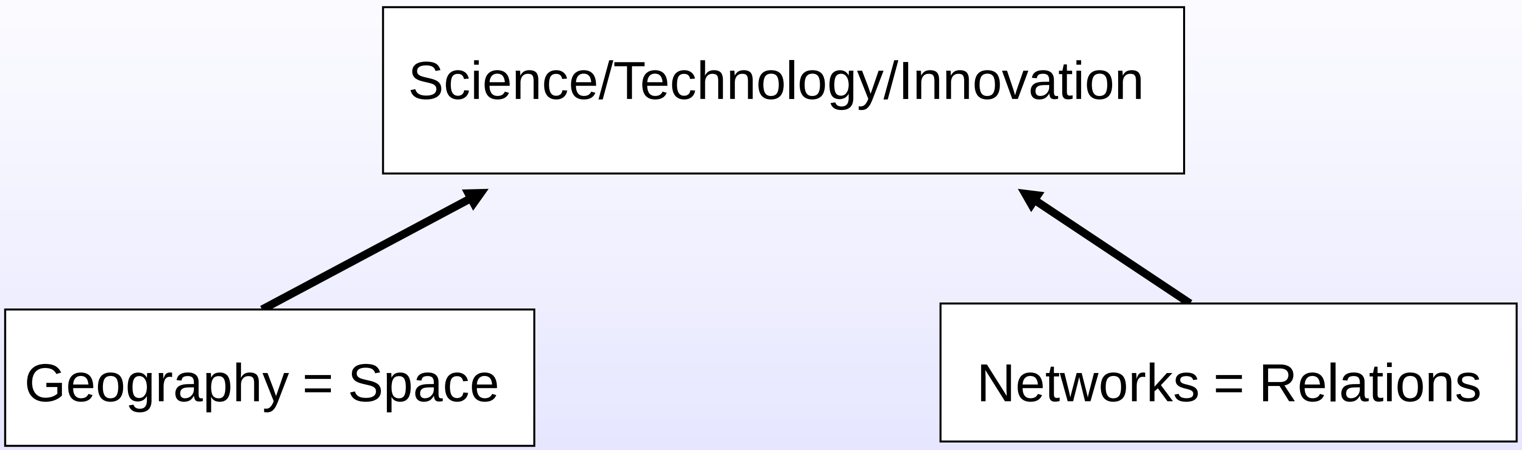
˛CERIS-CNR

(National Research Council - Institute for Economic Research on Firms and Growth)

Consiglio Nazionale delle Ricerche CERIS ISTITUTO DI RICERCA SULL' IMPRESA E LO SVILUPPO

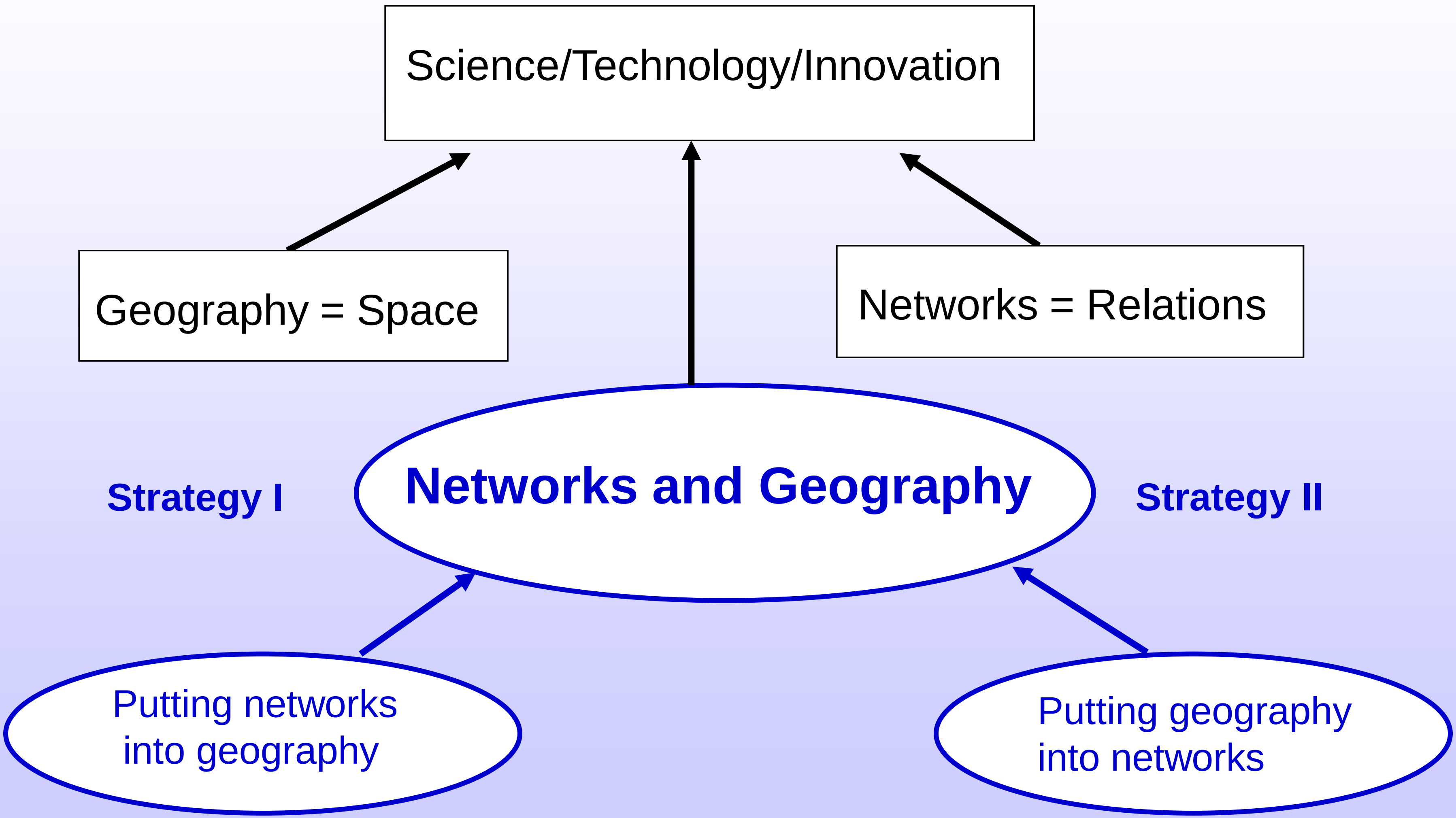
A wider framework

Networks and Geography in the economics of S&T



A wider framework

Networks and Geography in the economics of S&T



Networks and Geography

Strategy I	Strategies	Strategy II
Putting networks into geography		Putting geography into networks
Relational vs. Spatial proximity	Object of analysis	Networks of “geographically-defined” meso/macro nodes
Space = Proximity my behaviour = f (neighbours’) Who is my neighbour? • Someone living nearby • Someone I frequently interact with	Rationale of the analysis	Who establish and acts relations? Agents/organizations = micro level However micro behaviours are influenced by unobservable “local” conditions/interactions; thus the need for “meso/macro” analysis
Social Network Analysis **Spatial Econometrics**: Spatial + Relational weights	Analytical Tools	Social Network Analysis Network Topology Space = Distance -> **Gravity models**

Aims of the presentation

Innovation activity is affected by spatial concentration at all geographical levels (Nuts2, Nuts3, TTWA, etc). Empirics shows that R&D institutions (universities, govt.labs, H-T firms) do cluster

How do scientific information and knowledge flow between these clusters/regions?

- According to diffusive patterns based on spatial contiguity (**unintended spatial spillover** à la Acs, Anselin and Varga, 2002)?
- According to intentional relations based on a-spatial networks (**knowledge barter exchange** à la Cowan and Jonard, 1999)?

We analyse the information and knowledge flows associated with patents and co-patents in Europe (EU15: 171 NUTS2 regions) to:

- Measure the role of geography and relations
- Study the impact of EU S&T policy (w.r.t. Framework programmes)

Background literature

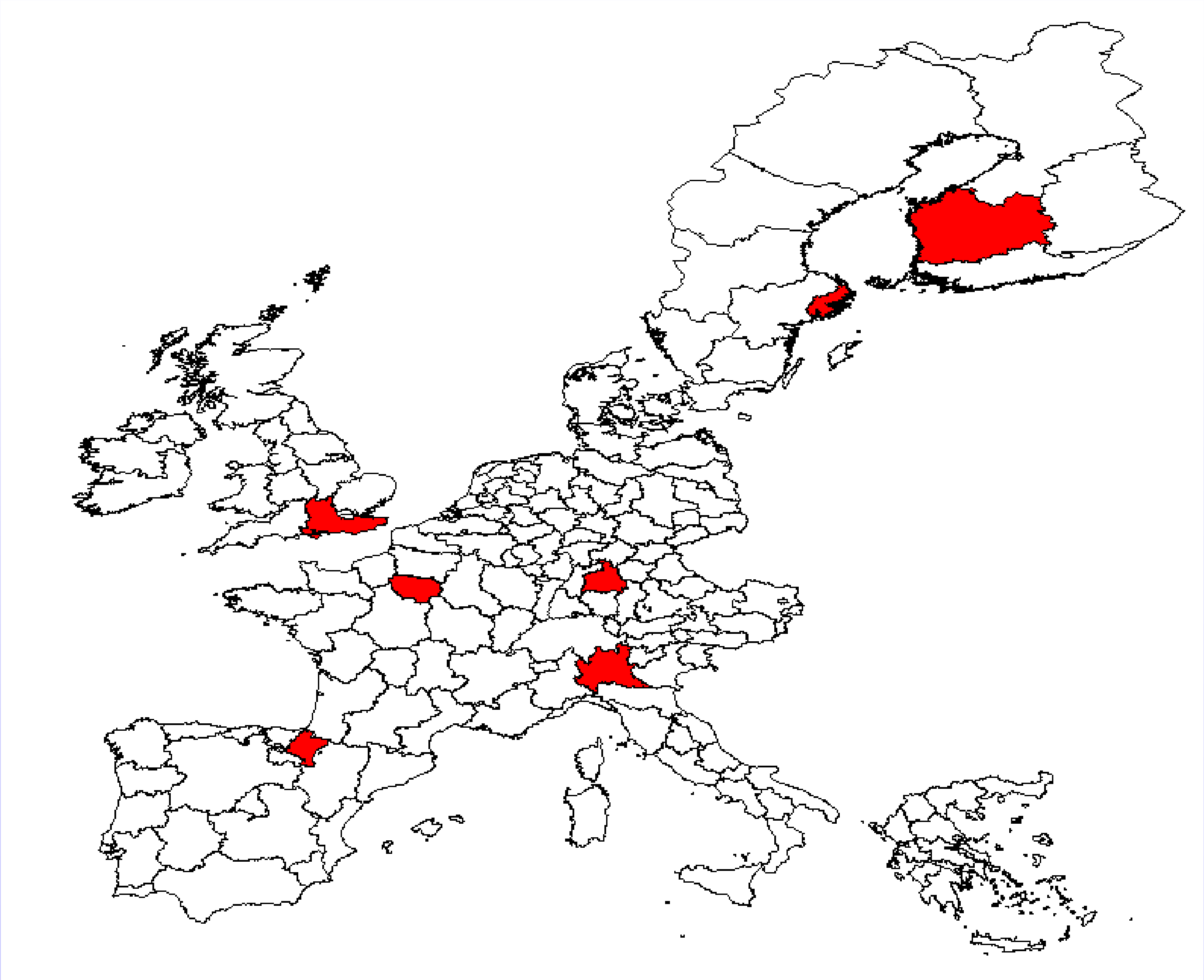
Innovation activity and networks:

Griliches, 1979; Jaffe A.B., Henderson R., Trajtenberg M., 1993; Audretsch, Feldman, 1996; Cowan and Jonard, 1999; Paci and Usai, 2000; Breschi and Lissoni, 2004 and 2009; Maggioni and Uberti, 2005 and 2008, Maggioni, Nosvelli and Uberti, 2007, Maggioni, Uberti and Usai 2011, Le Sage and Pace, 2008 Picci, 2010 and many others

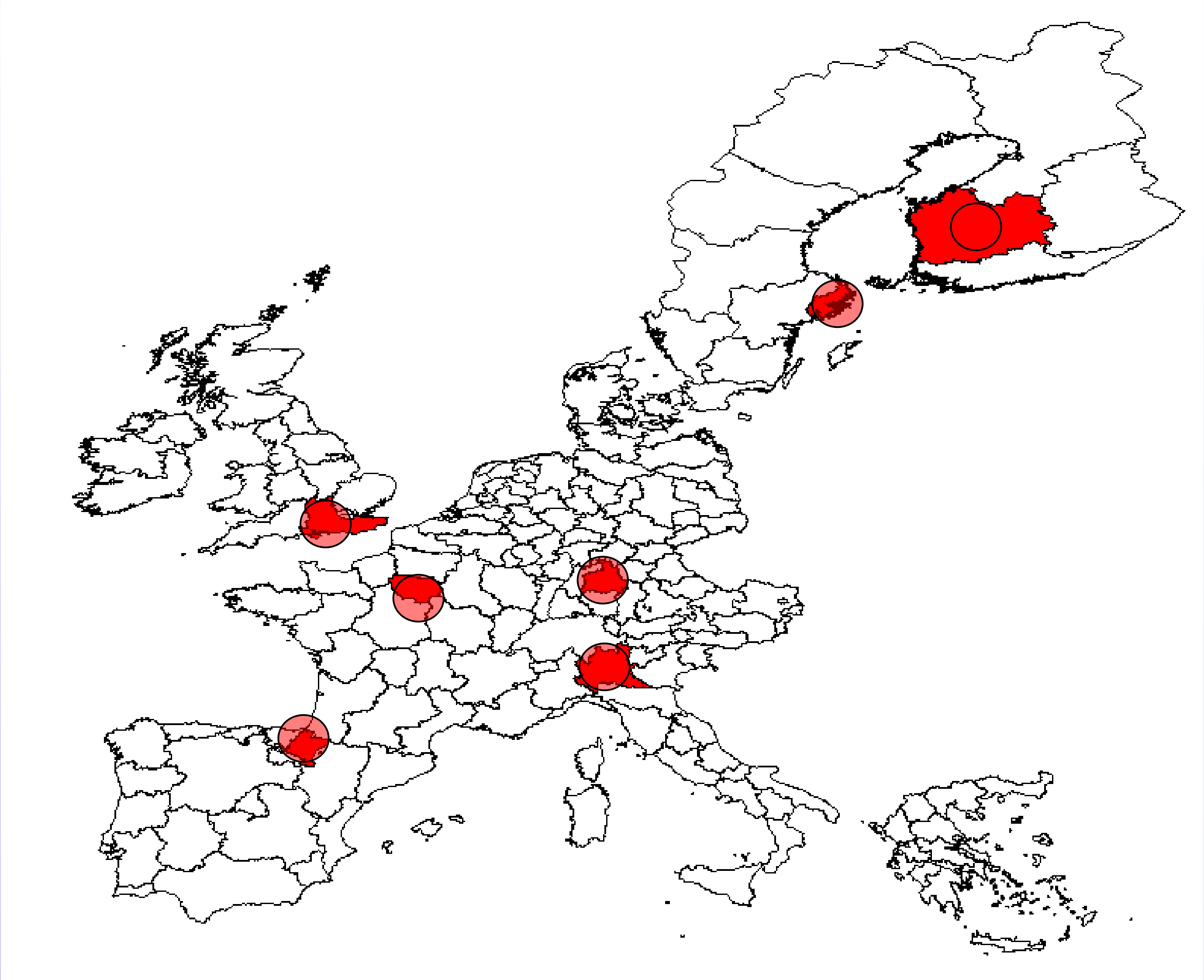
Spatial econometrics and innovation:

Acs, Anselin and Varga, 2002; Fischer and Varga, 2003; Bottazzi and Peri, 2003, Greunz, 2003; Bode E., 2004; Moreno, Paci and Usai, 2005, Autant-Bernard and LeSage, 2009; Usai, 2010; Varga et al. 2010 and many others

Geographical diffusion: unintended knowledge spillovers



Geographical diffusion:
unintended knowledge spillovers



Geographical diffusion:
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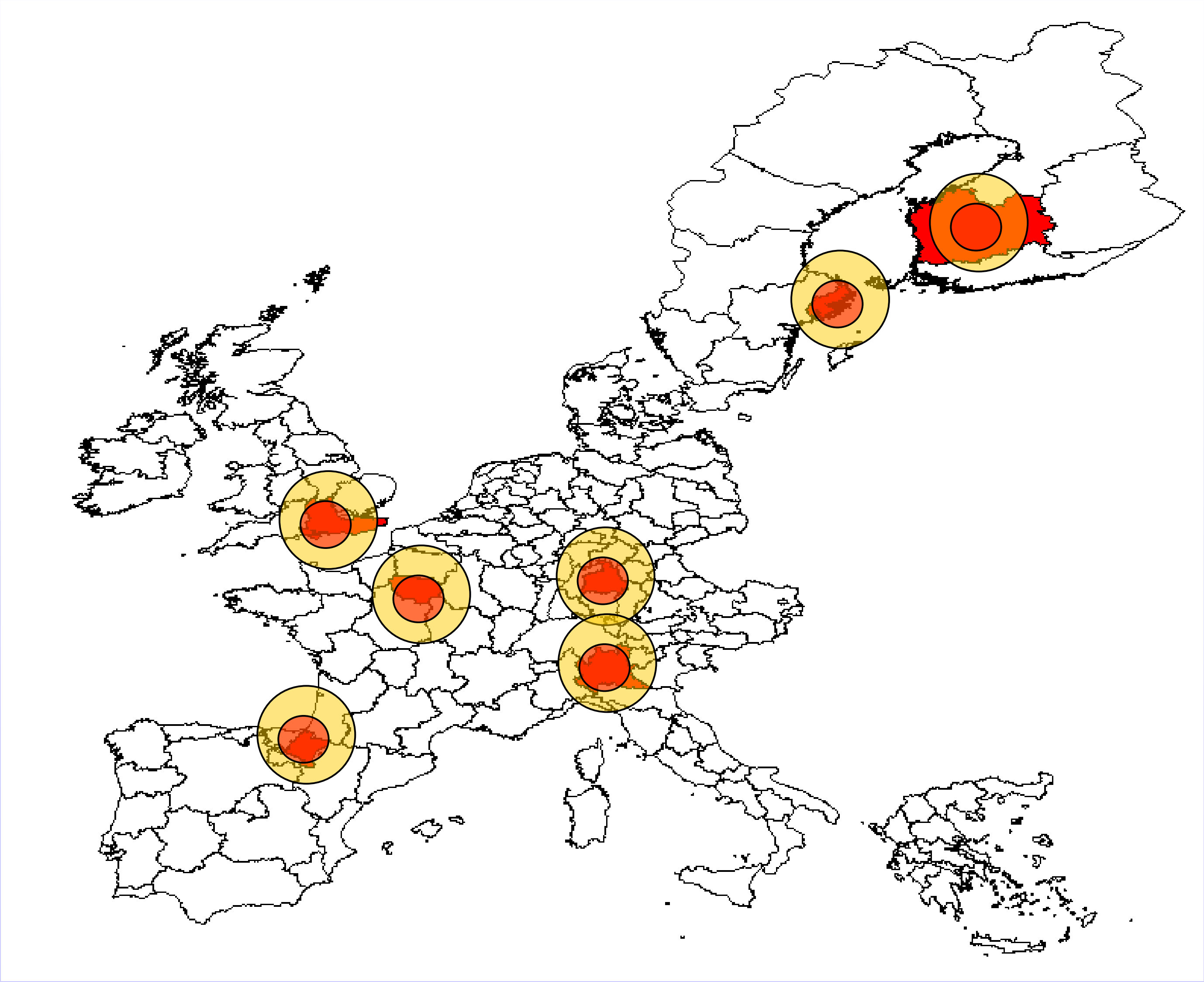

Geographical diffusion:
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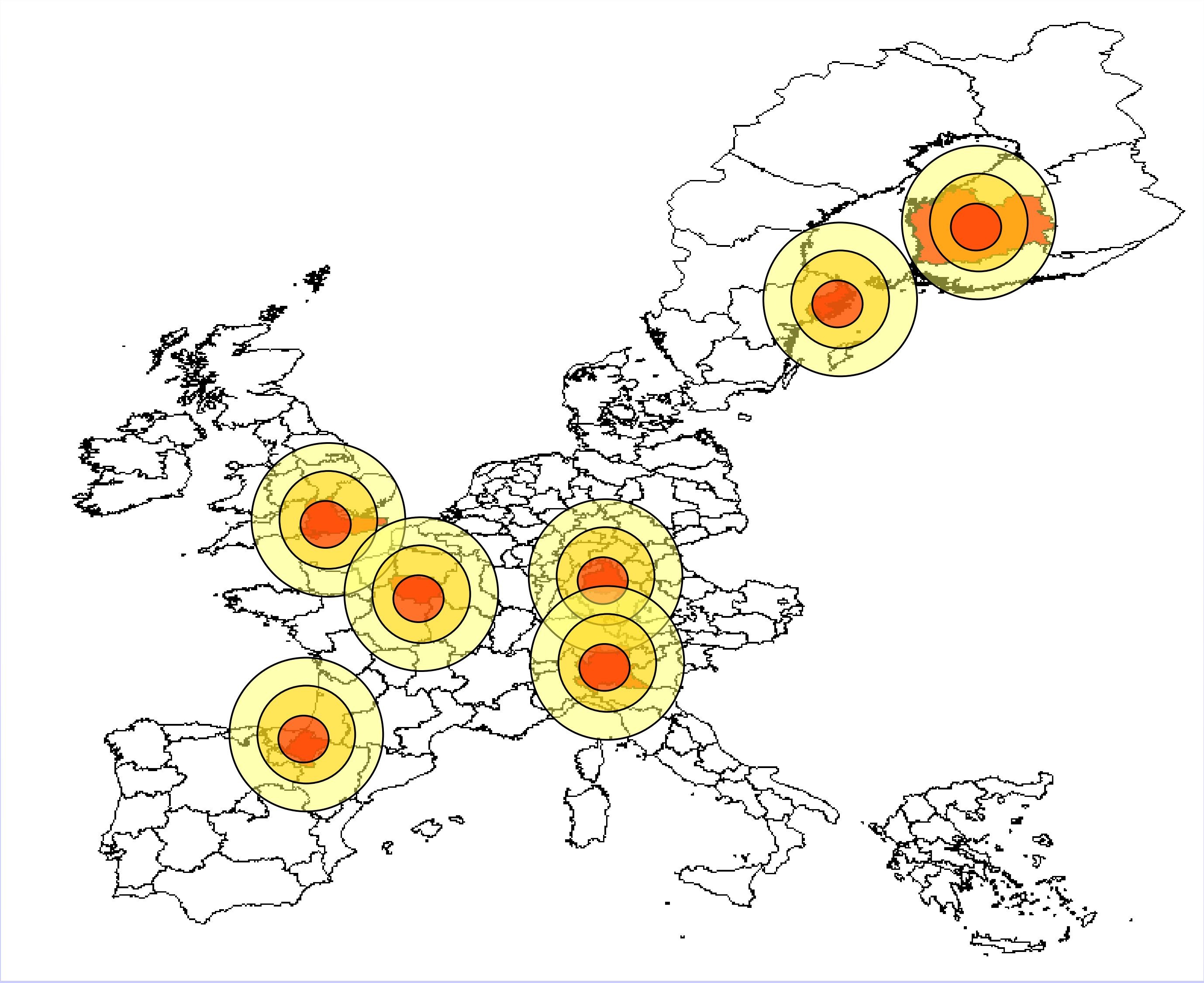

Geographical diffusion:
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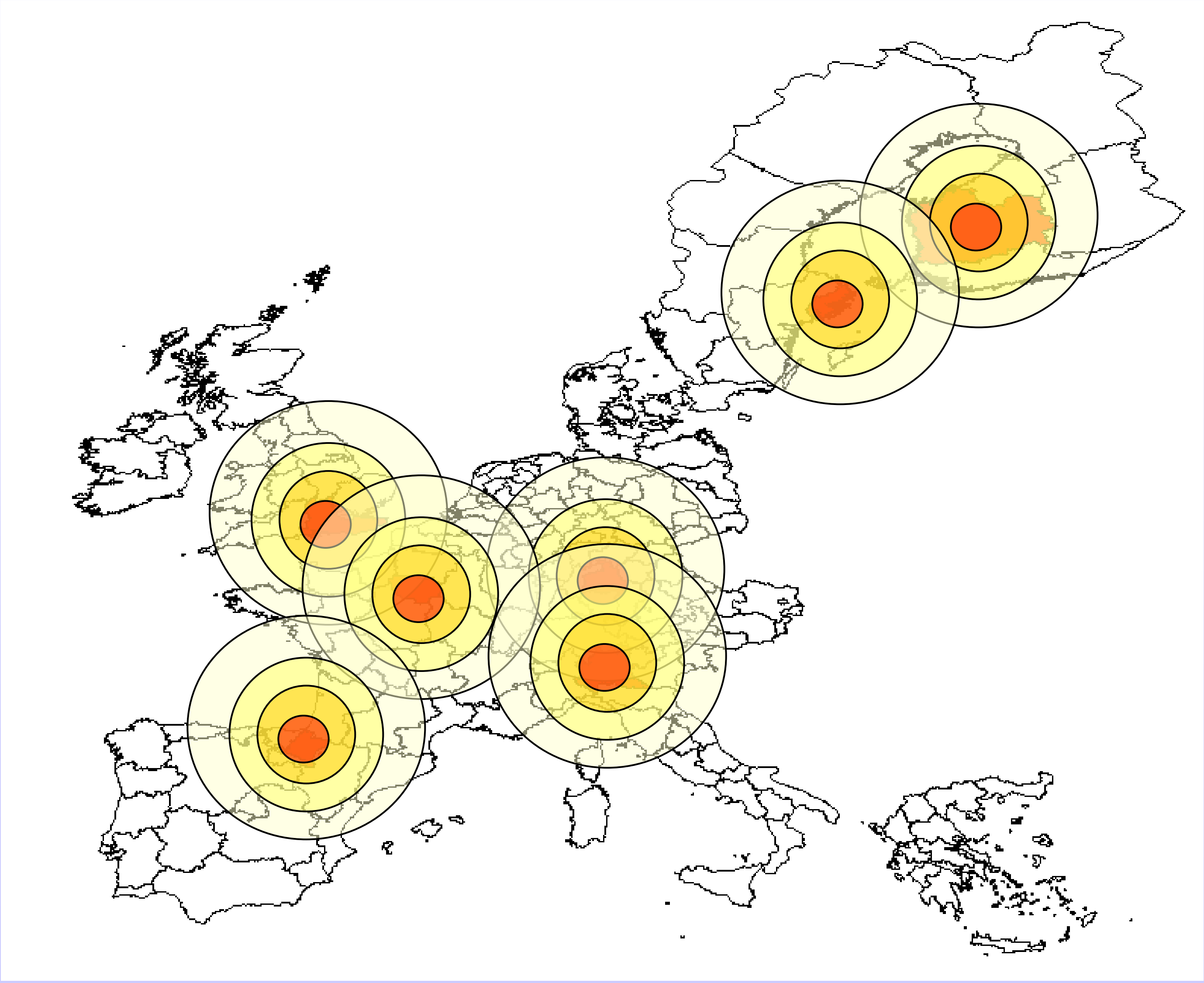
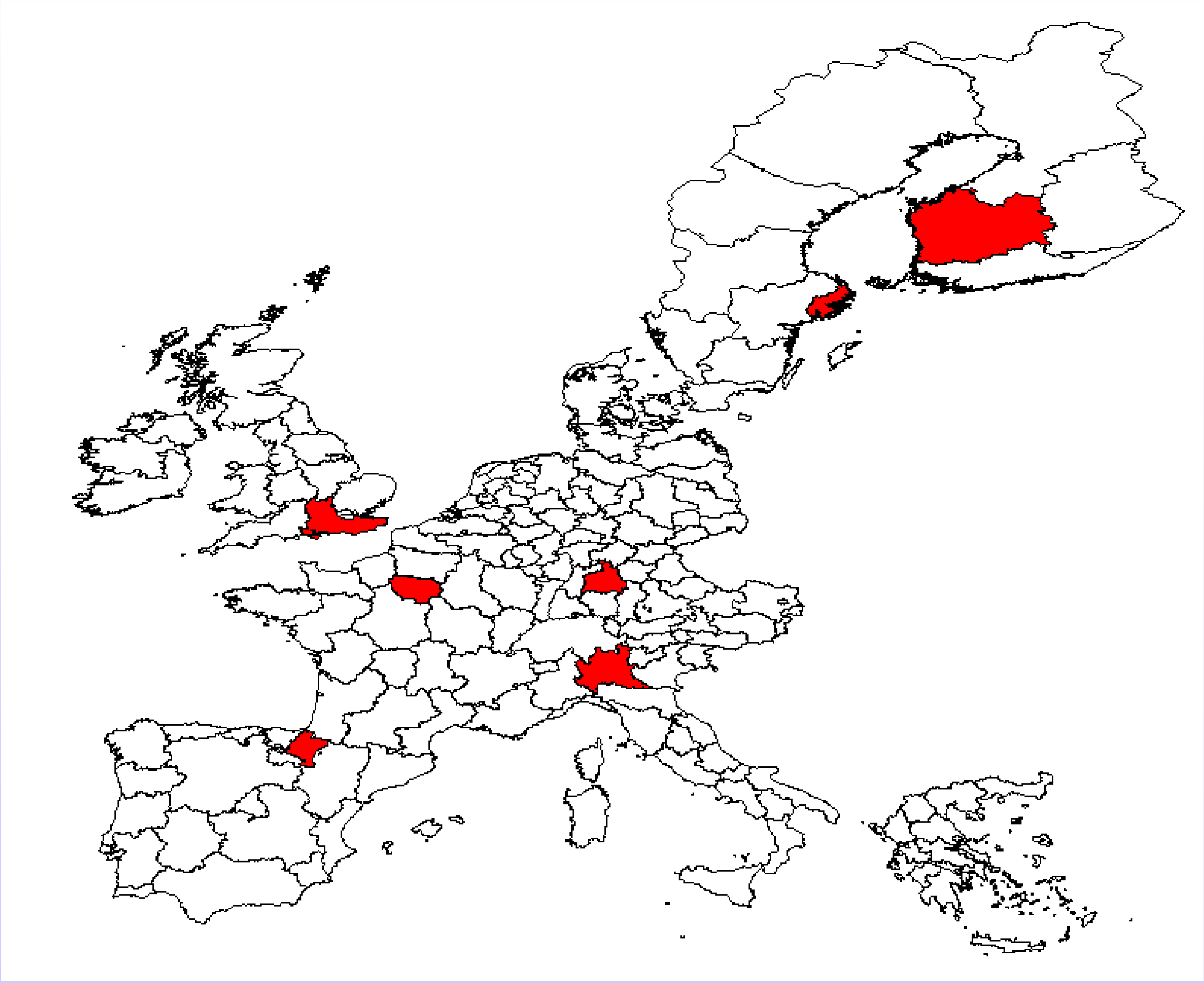


Relational networking: intentional knowledge barter exchange



Relational networking:
intentional knowledge barter exchange

How to measure relational networking?

Through the EU 5th Framework Programme (1998-2002)

Aim of **EU 5FP** : “to integrate different research areas and to develop a critical mass of European resources in S&T”.

Total number of financed contracts: 16,085

We select contracts with a network structure (mainly joint research projects) and based our analysis on **6,755** networks between institutions (**42%** of total 5FP contracts): average membership being equal to 7 (6 participants + 1 coordinator).

We aggregate these “institutional” networks at the regional level to:

- detect the unobservable structure of S&T knowledge flows;
- compare geographic and relational autocorrelation phenomena;
- test the robustness of our previous results to enlarged sample of regions, different networks structures and link value patterns;
- study the effect of EU S&T policy (Framework Programmes)

Before the analysis:
A logical guide to the presentation

In this paper we measure the effect of proximity on innovative performance (by spatial e'trix estimation techniques). Proximity (Maggioni et Al. 2007) has a Geographic and a Relational dimensions (**2 dimensions: GEO, REL**)

Since the actual relational structure measured by 5FP research networks is unobservable, we allow for different network structures (by limiting ourselves to "regular" patterns we identified 6 structures: **A, B, C, D, E, F**)

For each structure we allow also for different criteria for evaluation of links (5 links values: **1, N, L, FS, FA**)

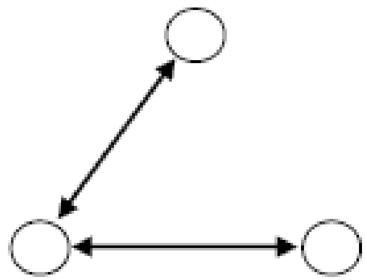
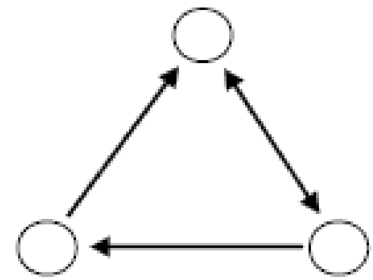
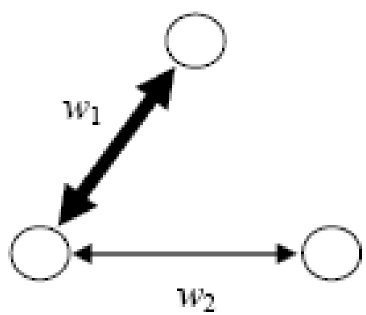
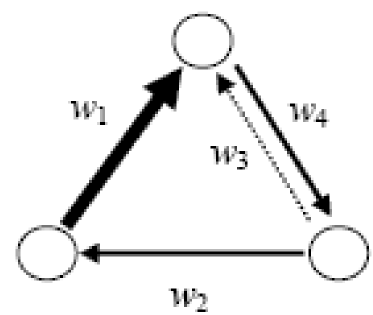
Econometric analysis is designed in order to detect which of the different specification of relational proximity is more relevant.

Ex-ante, 3 possible results:

- Results are robust to all specification = irrelevance of specification
- Results are significant and different for any specification = need for case studies a/o field experiments
- Results are significant only for a given specification = **exact identification**

A logical guide to the presentation

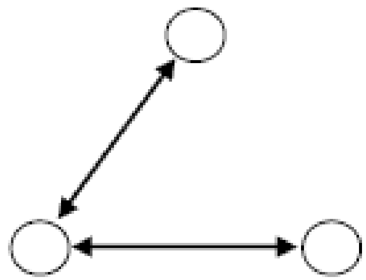
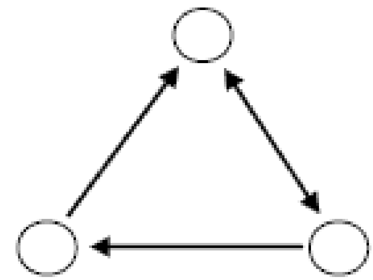
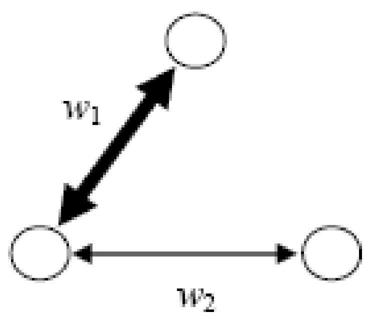
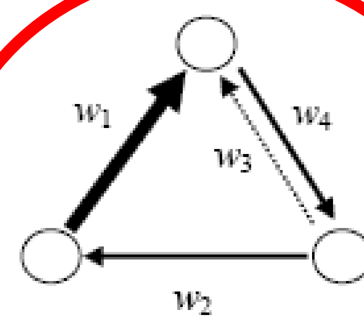
Link values and direction

Links	**Undirected**	**Directed**
Binary	 BUN	 BDN
Weighted	 WUN	 WDN

Source: Fagiolo et al. 2007

A logical guide to the presentation

Link values and direction

Links	Undirected	Directed
Binary	 BUN	 BDN
Weighted	 WUN	 WDN

Source: Fagiolo et al. 2007

A logical guide to the presentation
Link values

For each structure we have to allow also for different criteria for evaluation of links (**5 links values**: **1**, **N**, **L**, **FS**, **FA**). In other words we assume that each links is valued.

1 a constant value, irrespective of the number of nodes in the net **1**

N a value which is inversely dependent on the number of nodes in the net **1/N**

L a value which is inversely dependent on the number of links in the net **1/L**

FS the total funding of contract divided equally among participants **F/N**

FA the total funding of contract divided unequally among participants

The coordinators gets **2F/(N+2)**

each participant gets **F/(N+2)**

since **2F/(N+2)**+ **NF/(N+2) = F**

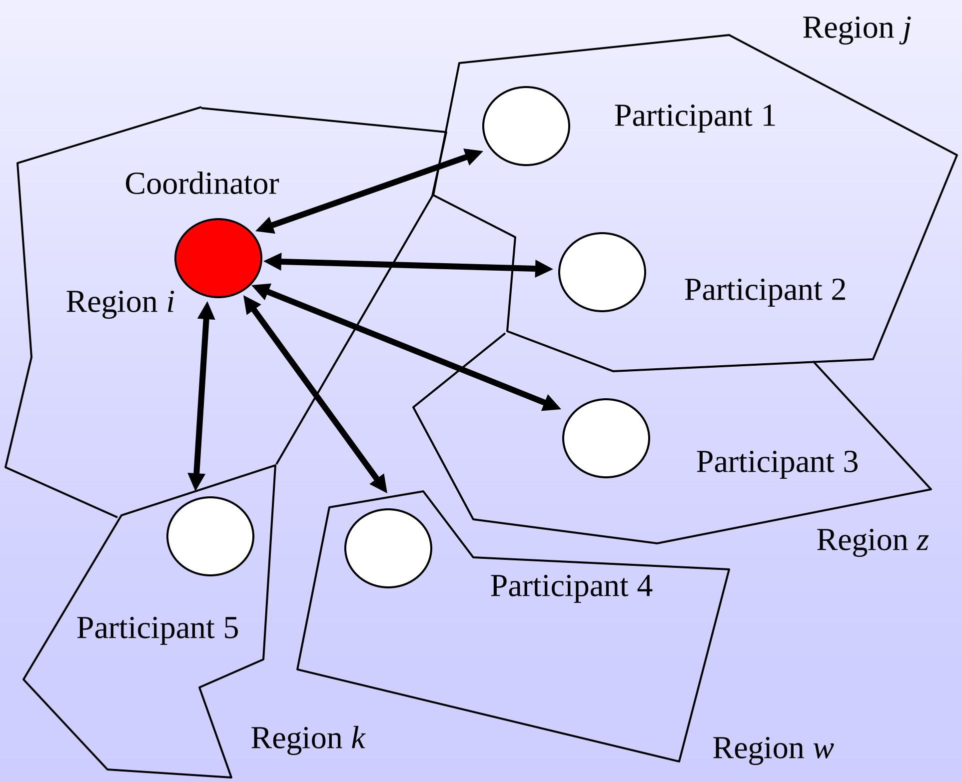
In a 5 nodes net, therefore each link may be alternatively valued:

1 $_1$ **1/5** $_N$ **1/10 or 1/4** $_L$ **F/5** $_{FS}$ **F/7**part. + **2F/7**coord. $_{FA}$

The weights matrices: spatial vs. relational

- Spatial weight matrix: rook procedure (in Europe not too dissimilar from queen procedure)
- Relational weight matrix: a 3 + 1 steps procedure based on 5FP

1 contract between institutions



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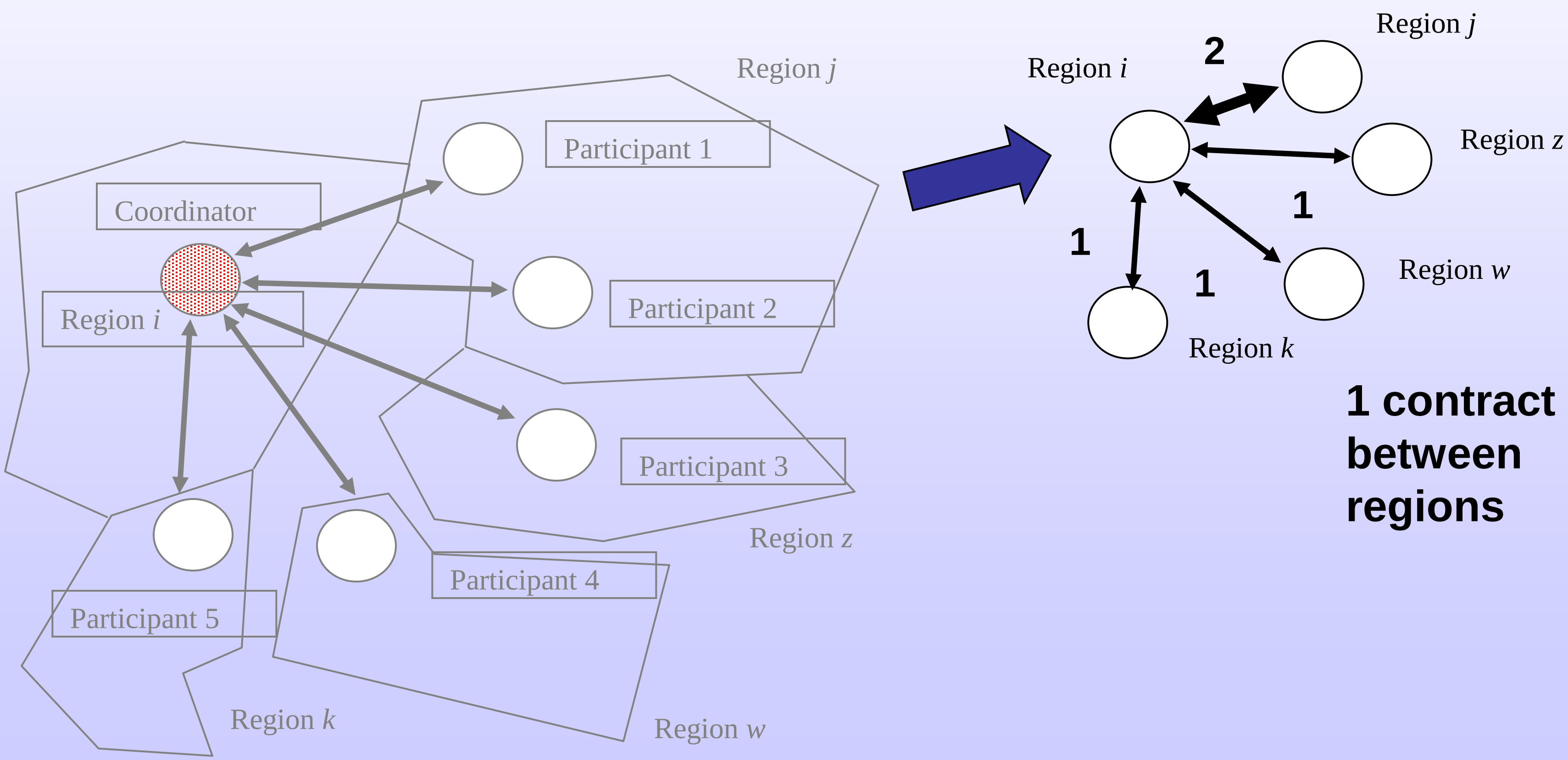
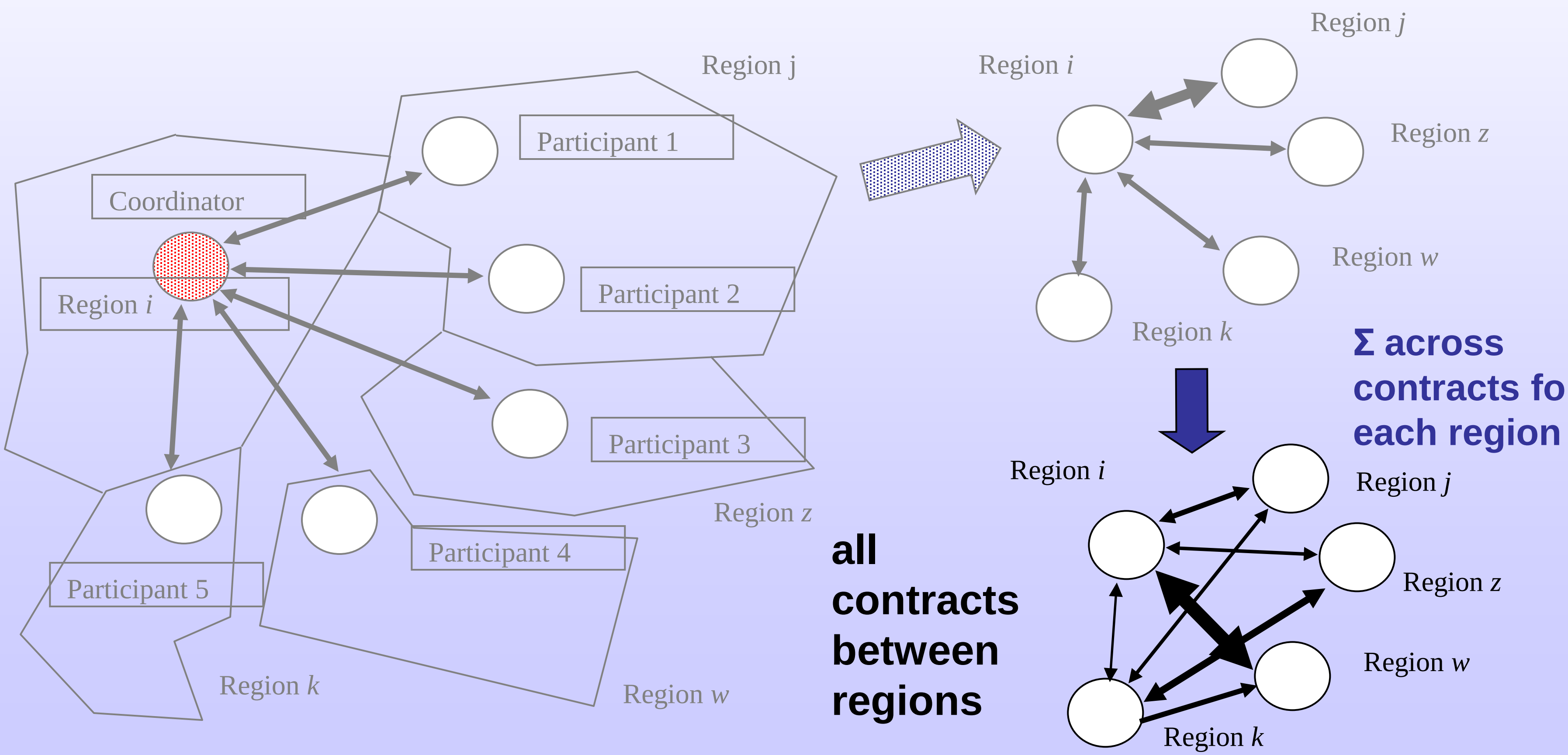


1 contract between regions

The weights matrices: spatial vs. relational

- Spatial weight matrix: rook procedure (in Europe not too dissimilar from queen procedure)
- Relational weight matrix: a 3 + 1 steps procedure based on 5FP



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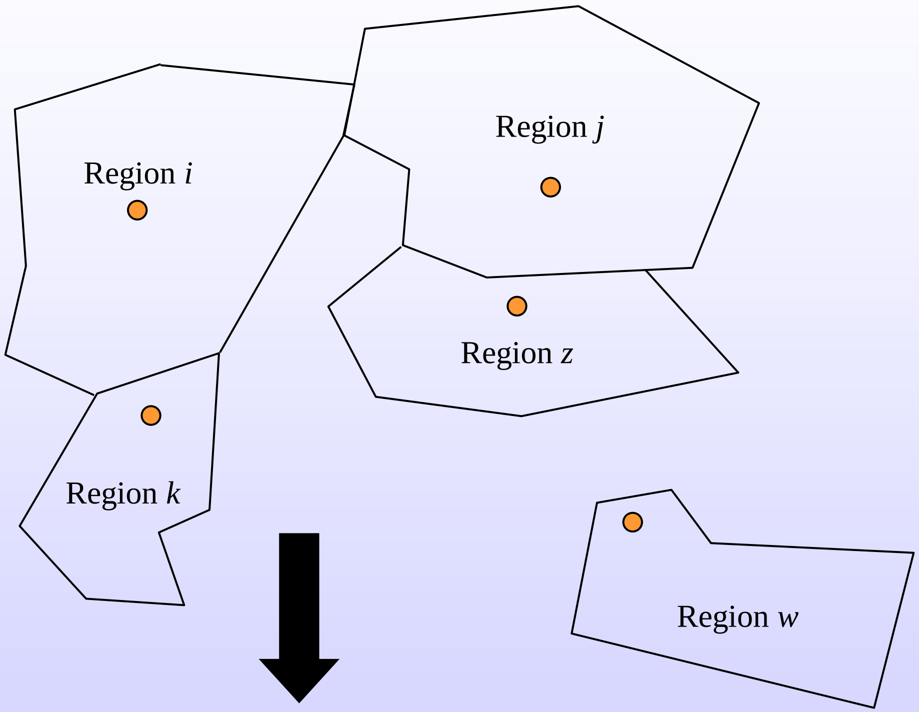
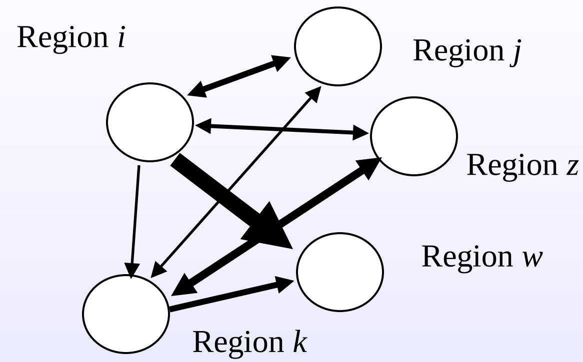




regions	i	j	k	w	z
i		1	1	0	0
j	1		0	0	1
k	1	0		0	0
w	0	0	0		0
z	0	1	0	0	

Geograph. Proximity (contiguity) $\neq$ Relational proximity (intensity)

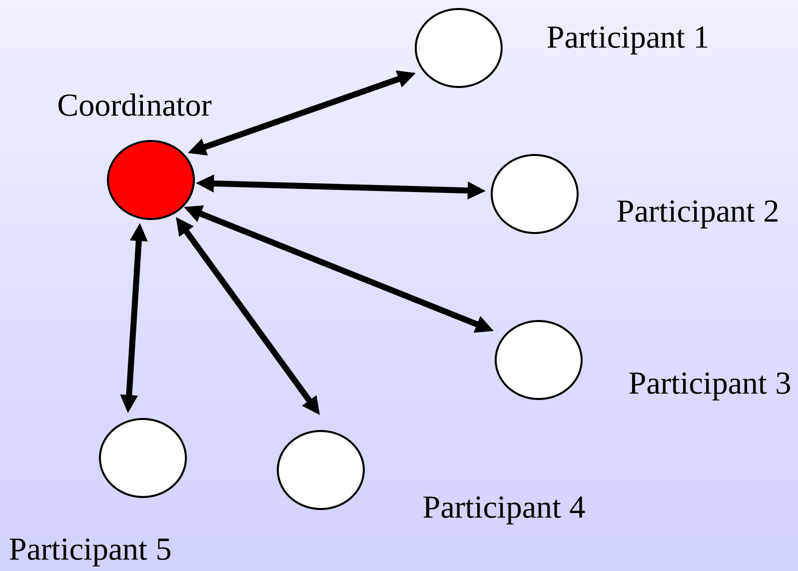
regions	i	j	k	w	z
i		12	3	38	5
j	7		3	0	0
k	0	3		6	3
w	0	0	0		0
z	8	0	0	0	

Relational proximity à la Maggioni et Al (2007)

hierarchical vs. a-hierarchical

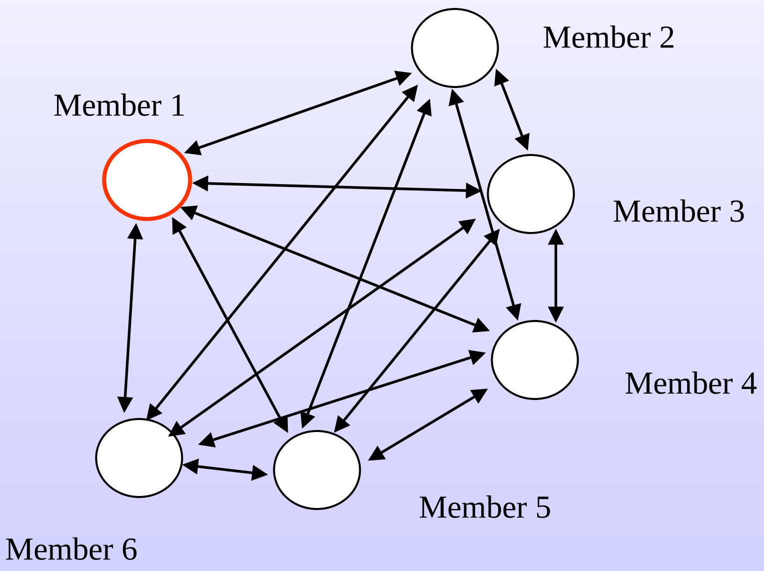
hierarchical network

information flows only between the coordinator-participant couplets

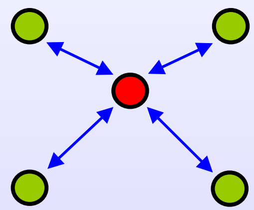
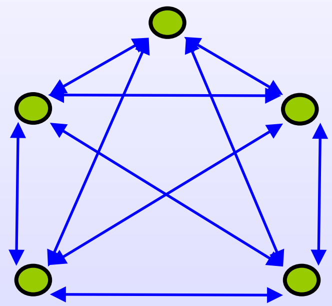
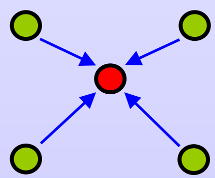
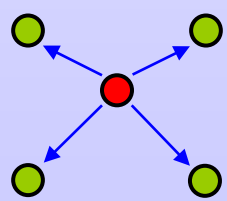
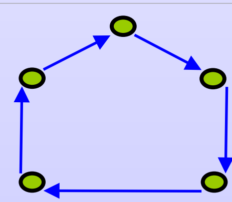
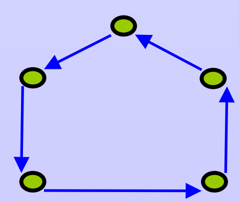


a-hierarchical network

information flows among all members

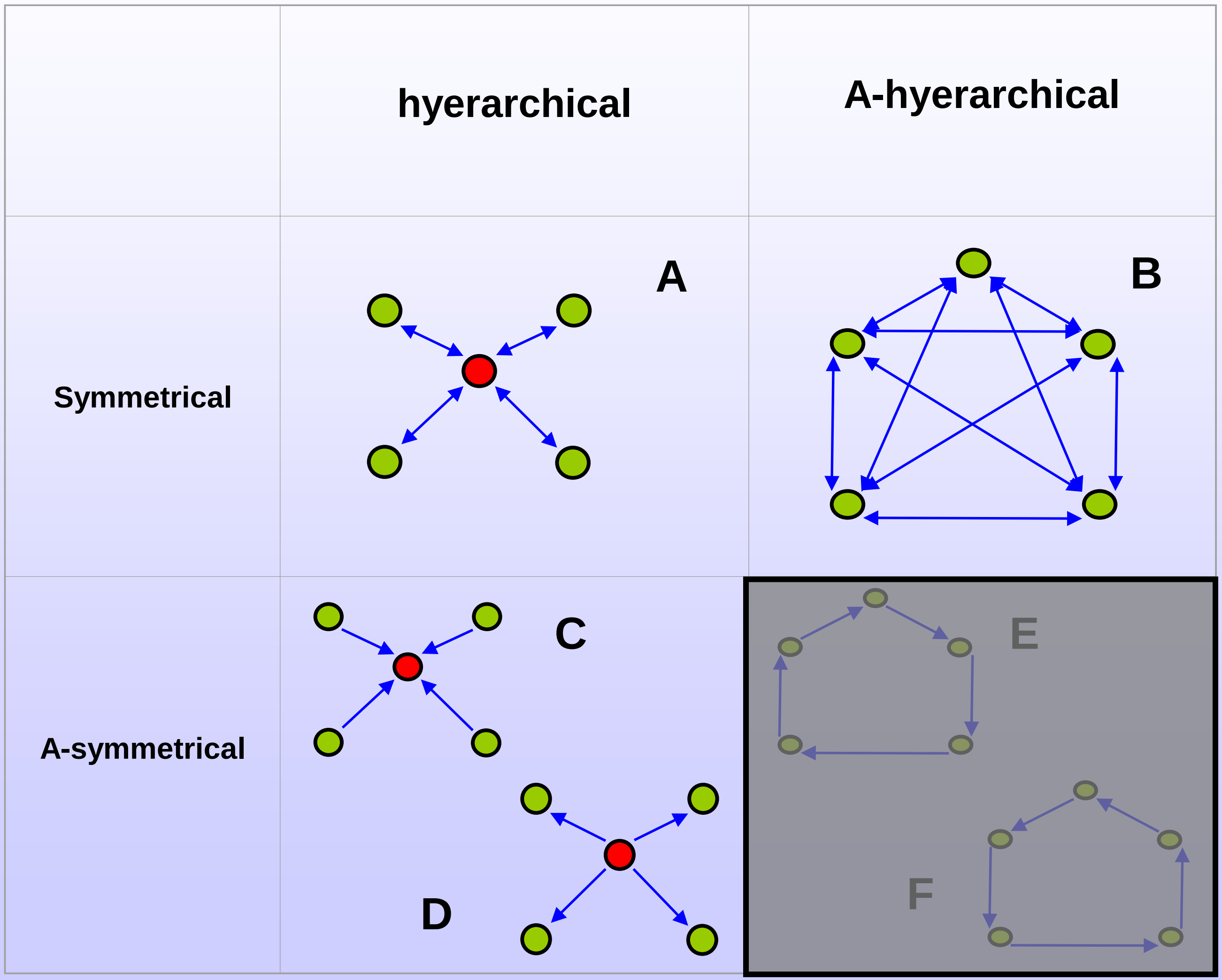


Relational proximity (a complete framework)
hierarchical/A-hierarchical vs. Symmetrical/a-symmetrical

	hyerarchical	A-hyerarchical
Symmetrical	 A	 B
A-symmetrical	 C  D	 E  F

Relational proximity (a complete framework)

hierarchical/A-hierarchical vs. Symmetrical/a-symmetrical



E and **F:**

Logical exclusion

Geographical spillover and relational networking in patenting activity:

A spatial (geographic/relational) dependence analysis

Area:	171 European regions at Nuts2 level (EU 15) (exceptions: DK Nuts0, LUX Nuts0, UK Nuts1)
Time Period:	dependent variable (average 2005-2006) indep. variables (average 1999-2004)
Dependent variable:	**patent** applications per million labour force (source: OECD)
Spatial Weights:	Geographical contiguity matrices (contiguity) Relational proximity matrices (FP5)

TABLE 1: Testing for the existence of: **GEO**graphic and **REL**ational autocorrelation: Moran's I

VARIABLE	WEIGHT	Moran's I	PROB
PAT	GEO	0.118	0.002
PAT	REL A1	0.059	0.000
PAT	REL AN	0.084	0.014
PAT	REL AL	0.061	0.001
PAT	REL AFS	0.043	0.010
PAT	REL AFA	0.043	0.009
PAT	REL B1	0.063	0.000
PAT	REL BN	0.069	0.000
PAT	REL BL	0.069	0.000
PAT	REL BFS	0.054	0.000

VARIABLE	WEIGHT	Moran's I	PROB
PAT	REL C1	0.070	0.000
PAT	REL CN	0.074	0.000
PAT	REL CL	0.076	0.001
PAT	REL CFS	0.074	0.000
PAT	REL CFA	0.074	0.000
PAT	REL D1	0.058	0.000
PAT	REL DN	0.057	0.002
PAT	REL DL	0.056	0.005
PAT	REL DFS	0.041	0.039
PAT	REL DFA	0.041	0.036

Moran's I computed on dependent variable PAT (all + and significant)
(patent "inventor-based", average value of the period 2005-06)
20 different "Spatial" (1 GEO and 19 REL) weight matrices

possibly spurious spatial correlation!!

GEO vs. REL in patenting activity: a knowledge production function framework

SEM (Spatial Error Model) ML estimation, double-log specification

$$PAT_{it} = \beta_0 + \beta_1 BizRD_i^{t-n} + \beta_2 GovRD_i^{t-n} + \beta_3 INN_i^{t-n} + \beta_4 PROD_i^{t-n} + + \beta_5 ACCESS_i^{t-n} + \beta_6 COORD_i^{t-n} + \beta_6 BETW_i^{t-n} \lambda W_i \ \varepsilon^{t-n} + \xi_i^{t-n}$$

SAR (Spatial Autoregressive Model) ML estimation, double-log specification

$$PAT_{it} = \rho WPAT_{it} + \beta_0 + \beta_1 BizRD_i^{t-n} + \beta_2 GovRD_i^{t-n} + \beta_3 INN_i^{t-n} + + \beta_4 PROD_i^{t-n} + \beta_5 ACCESS_i^{t-n} + \beta_6 COORD_i^{t-n} + \beta_6 BETW_i^{t-n} + \nu_i^{t-n}$$

BizRD = business R&D (Eurostat: average 1999-2003)
GovRD = government R&D (Eurostat: average 1999-2003)
INN = Location Quotient HT patent (reference area: EU 15)
PROD = Location Quotient HT manufacturing (Eurostat: average 1999-2003)
ACCESS = Multimodal accessibility (ESPON 1999)
COORD = n. of contract coordinated by a regional institution (EU 5FP)
BETW = betweenness centrality of region i (EU 5FP)

TABLE 2: Testing for the existence of: **GEO**graphic **or** **REL**ational "spatial" autocorrelation: regressions

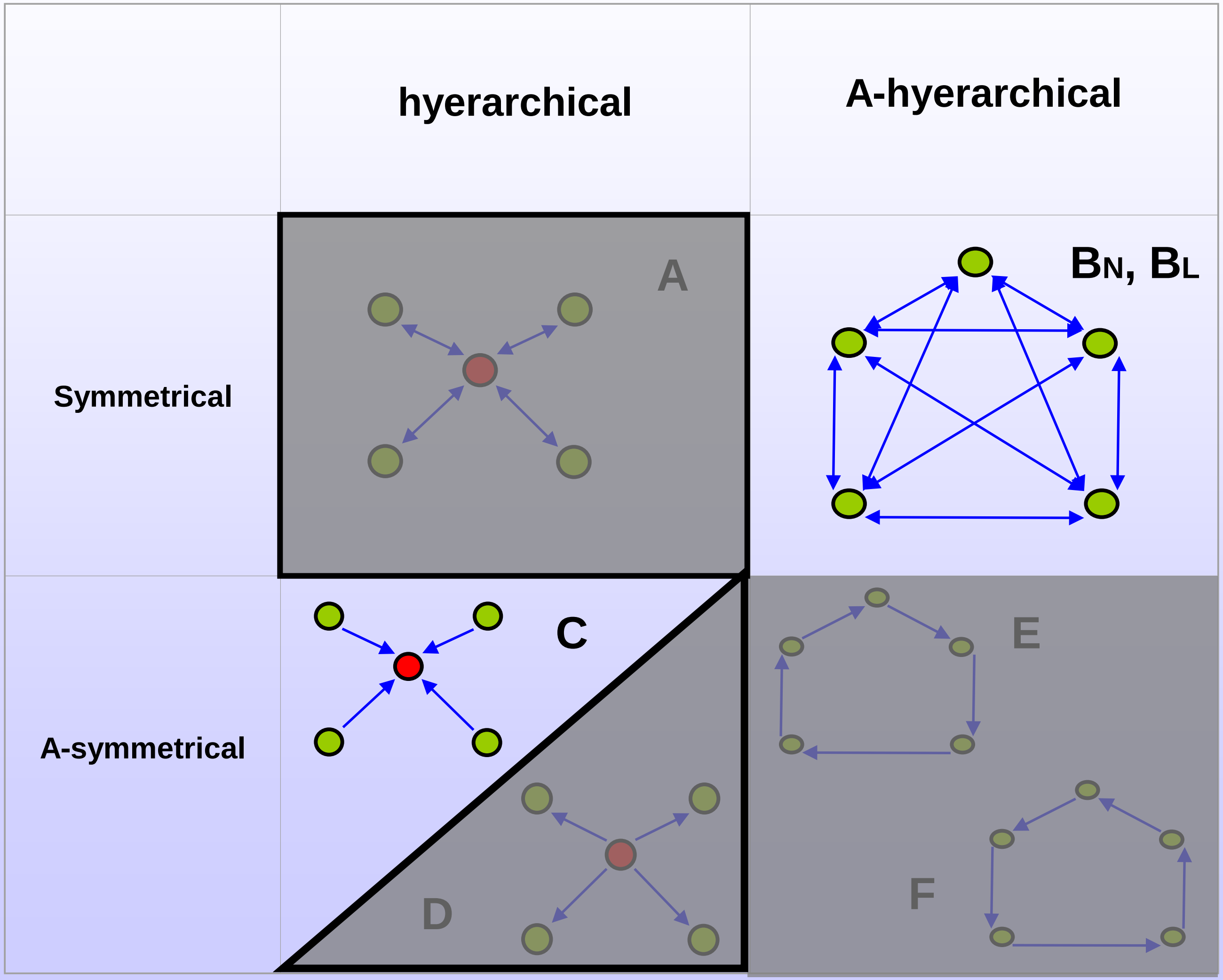
Weight Matrix	Moran's I / DF	Probability	Model strategy
GEO	0.1009	0.051	LAG
B_1	**-0.0001**	**0.233**	**OLS**
B_N	0.0088	0.049	LAG
B_L	0.0225	0.091	ERROR
B_{FS}	**-0.0037**	**0.678**	**OLS**
C_1	0.0464	0.007	LAG
C_N	0.0512	0.007	LAG
C_L	0.0541	0.009	LAG
C_{FS}	0.0475	0.011	LAG
C_{FA}	0.0472	0.011	LAG
A	**0.011**	**0.22**	**OLS**
$D_{\_}$	**0.0002**	**0.673**	**OLS**

11 relational

Moran's I (errors) based on different weight matrices (1 GEO, 11 REL)

No "spatial" autocorrelation for these A and D net structures

The relational weights matrices:
hierarchical/a-hierarchical vs. Symmetrical/a-symmetrical



A and **D:**

E'trix Exclusion

GEO only

REL only

TABLE 3: Testing for the existence of: **GEO**graphic **or** **REL**ational autocorrelation

***	1% l.o.s.
**	5% l.o.s.
*	10% l.o.s.
	> 10% l.o.s.

		Geo Prox	Relational Proximity						
	OLS	*contiguity*	B_N	B_L	C_1	C_N	C_L	C_{FS}	C_{FA}
Variables									
Constant	5.653	4.726	3.464	5.796	3.568	3.428	3.463	3.691	3.71
BIZR&D	1.091	0.966	1.06	1.084	1.073	1.068	1.065	1.073	1.074
GOVR&D	-0.102	-0.072	-0.096	-0.121	-0.083	-0.089	-0.089	-0.073	-0.073
ACCESS	0.001	2.72E-04	0.001	0.001	0.001	0.001	0.001	0.001	0.001
PROD	1.038	1.021	1.023	1.025	1.039	1.038	1.039	1.041	1.041
INN	0.066	0.054	0.054	0.08	0.061	0.062	0.063	0.058	0.058
COORD	-0.055	-0.055	-0.052	-0.056	-0.188	-0.195	-0.193	-0.181	-0.18
ρPAT		0.196	0.408		0.51	0.54	0.533	0.479	0.475
λPAT				0.485					
Obs.	171	171	171	171	171	171	171	171	171
LIK	-283.5	-280.31	-282.9	-282.5	-277.3	-276.2	-275.9	-278.1	-278.1
AIC	581.07	576.62	581.81	579.09	570.63	568.3	567.81	572.13	572.29

2 alternative specifications of a complete model GEO **and** REL autocorrelation

ML estimation, double-log specification

SAR (REL) + Spatially lagged independent Variable *WgeoPAT*

$$PAT_{it} = \rho WrelPAT_{it} + \beta_0 + \beta_1 BizRD_i^{t-n} + \beta_2 GovRD_i^{t-n} + \beta_3 INN_i^{t-n} + \beta_4 PROD_i^{t-n} + \beta_5 PERIPH_i^{t-n} + \beta_6 nMEMB_i^{t-n} + WgeoPAT_{it} + \nu_i^{t-n}$$

SAR (GEO) + Spatially lagged independent Variable *WrelPAT*

$$PAT_{it} = \rho WgeoPAT_{it} + \beta_0 + \beta_1 BizRD_i^{t-n} + \beta_2 GovRD_i^{t-n} + \beta_3 INN_i^{t-n} + \beta_4 PROD_i^{t-n} + \beta_5 PERIPH_i^{t-n} + \beta_6 nMEMB_i^{t-n} + WrelPAT_{it} + \mu_i^{t-n}$$

If data generation process has got both a GEOgraphical and a RELational component and we estimates separatedly these 2 components, we are using misspecified models

TABLE 4a: Testing for the existence of: **GEO**graphic **and** **REL**ational autocorrelation

GEO lagged indep. variable + REL Weight Matrix

Lagged variable	Coefficient	Probability	Weight matrix	Moran's I/DF	Probability	Model specification
W_GEO PAT	0.246	0.008	B_1	-0.0046	0.656	OLS
W_GEO PAT	0.246	0.008	B_N	0.0026	0.191	OLS
W_GEO PAT	0.246	0.008	B_L	0.0162	0.167	OLS
W_GEO PAT	0.246	0.008	B_{FS}	-0.0079	0.86	OLS
W_GEO PAT	0.246	0.008	C_1	0.0391	0.017	LAG
W_GEO PAT	0.246	0.008	C_N	0.0443	0.015	LAG
W_GEO PAT	0.246	0.008	C_L	0.0477	0.017	LAG
W_GEO PAT	0.246	0.008	C_{FS}	0.0391	0.028	LAG
W_GEO PAT	0.246	0.008	C_{FA}	0.0388	0.029	LAG

No "spatial" autocorrelation for B network structures

TABLE 4b: Testing for the existence of: **GEO**graphic **and** **REL**ational autocorrelation

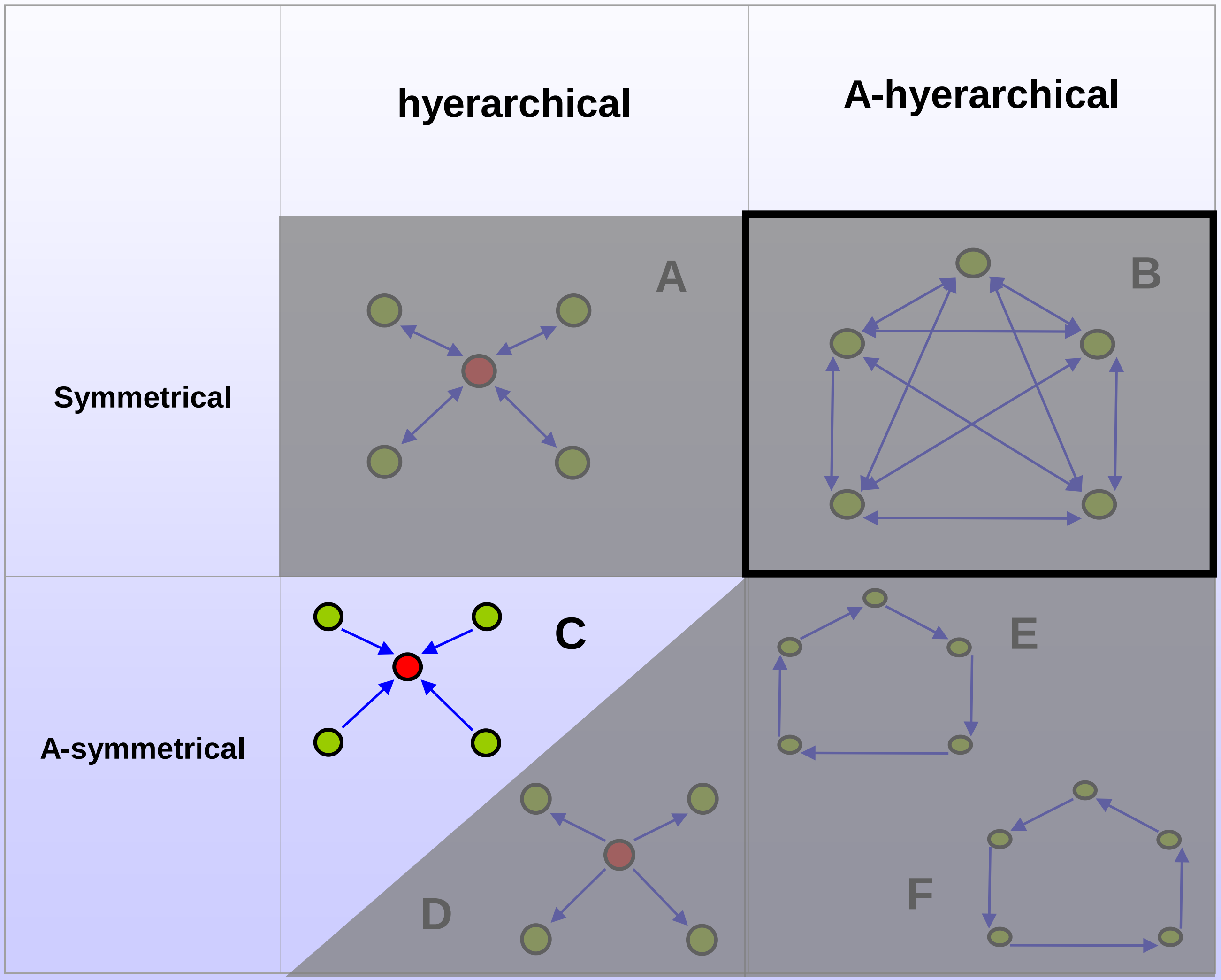
REL lagged indep. variable + GEO Weight Matrix

Lagged variable W	Coefficient	Probability	Moran's I/DF Weight matrix = GEO	Probability	Model specification
W_B_1 PAT	0.499	0.344	0.094	0.065	OLS
W_B_N PAT	0.401	0.362	0.096	0.059	OLS
W_B_L PAT	0.258	0.326	0.099	0.053	OLS
W_B_{FS} PAT	0.579	0.276	0.098	0.055	OLS
W_C_1 PAT	0.534	0.001	0.084	0.093	LAG
W_C_N PAT	0.566	0.000	0.083	0.095	LAG
W_C_L PAT	0.556	0.000	0.085	0.089	LAG
W_C_{FS} PAT	0.499	0.001	0.083	0.097	LAG
W_C_{FA} PAT	0.495	0.001	0.083	0.096	LAG

No “spatial” autocorrelation for B network structures

The relational weights matrices:

hierarchical/a-hierarchical vs. Symmetrical/a-symmetrical



B:

E'trix Exclusion

GEO+REL

TABLE 5: Testing for the existence of: **GEO**graphic and **REL**ational autocorrelation

"control" variables not reported in the table

***	1% l.o.s.
**	5% l.o.s.
*	10% l.o.s.
	> 10% l.o.s.

	C1	CN	CL	CFS	CFA	GEO				
VARIABLE	COEFF	COEFF	COEFF	COEFF	COEFF	COEFF	COEFF	COEFF	COEFF	COEFF
COORD	-0.173	-0.182	-0.179	-0.165	-0.163	-0.181	-0.19	-0.187	-0.172	-0.171
BETW_C	0.006	0.006	0.005	0.004	0.004	0.004	0.004	0.003	0.002	0.002
W_GEO PAT	0.191	0.184	0.184	0.199	0.2					
W_C_1 PAT						0.471				
W_C_N PAT							0.507			
W_C_L PAT								0.5		
W_C_{FS} PAT									0.438	
W_C_{FA} PAT										0.433
ρ REL	0.431	0.467	0.463	0.401	0.397					
ρ GEO						0.142	0.137	0.137	0.149	0.149
Obs.	171	171	171	171	171	171	171	171	171	171
LIK	-275.02	-274.02	-273.74	-275.57	-275.64	-275.39	-274.31	-274.04	-276.01	-276.1
AIC	570.05	568.04	567.49	571.14	571.28	570.79	568.62	568.08	572.04	573.19

Conclusion

This paper tests the joint role, within the innovation activity of European regions, of formal a-spatial networks between geographically distant region (intentional knowledge barter exchange) and diffusive patterns based on geographical contiguity (unintended knowledge spillovers).

Building on previous works we address two methodological issues:

- How to jointly estimates two different (GEO and REL) autocorrelation phenomena (weight matrix + lagged variable)
- How to model the unobservable structure and link value of actual knowledge flows within joint research project

Results show that:

- formal knowledge networks play a relevant role besides geographical spillovers;
- knowledge follows hierarchical structures (efficiency reasons?); therefore FP may sustain the “knowledge economy” but not regional cohesion if most coordinators are in core regions
- coordinating a large number of networks is not as important as being in the “right” networks (connected to other “hot spots”)

Future research

After 10-15 years on knowledge-science-technology nets …

- need to build a bridge between the "macro/descriptive" approach and the "micro-based" network formation/stability approach

How can we achieve it?

- ***theoretical models*** which take into account more realistic hypotheses on the nature of knowledge and on the informational asymmetries, i.e. mix Jackson and Wolinsky (1996), with Cowan and Jonard (2004);
- **behavioural experiments** on how people thinks and acts when they have to establish relations in order to solve complex problems requiring collaboration (Callander and Plott, 2005);
- **simulations** of the same task performed by "rational, utility maximising agents/algorithm" (based on Maggioni, Uberti, 2009);
- **field experiments (and case studies)** based on specific Joint Research projects;