SPATIAL DYNAMICS LAB ©

The Evolutionary Process of Knowledge Recombination & Smart Specialisation Strategies for Economic Development

Technology Evolution in Regional Economies
ERC StG #715631 – TechEvo

Dieter F. Kogler

dieter.kogler@ucd.ie

@dfkogler

www.ucd.ie/sdl

UCD DUBLIN

Economic & Social Research Institute (ESRI), Dublin, Ireland, November 7th, 2019.

TechEvo & SciTechSpace – Spatial Dynamics Lab

SPATIAL DYNAMICS LAB ©

TechEvo

Technology Evolution in Regional Economies

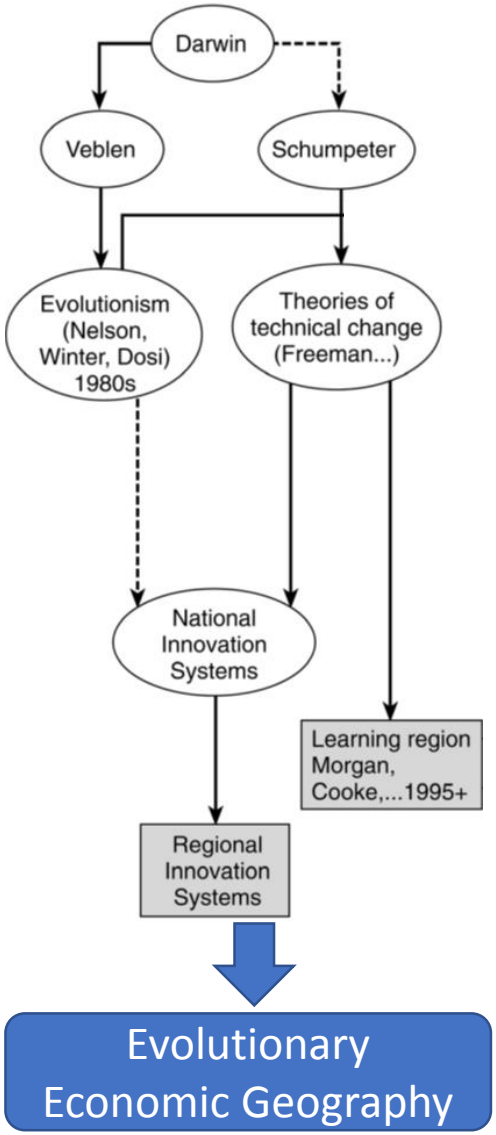
SciTechSpace

Science Technology Space

European Research Council

Science Foundation Ireland

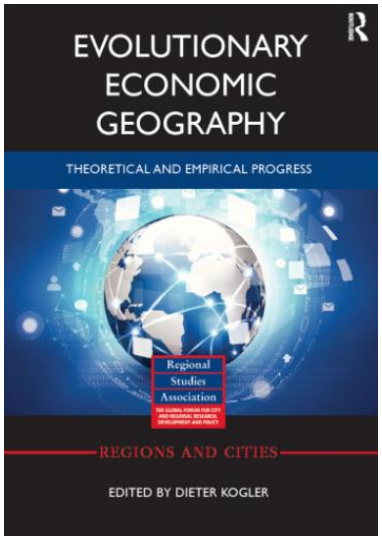
The Evolution of Knowledge – Unlike other Goods



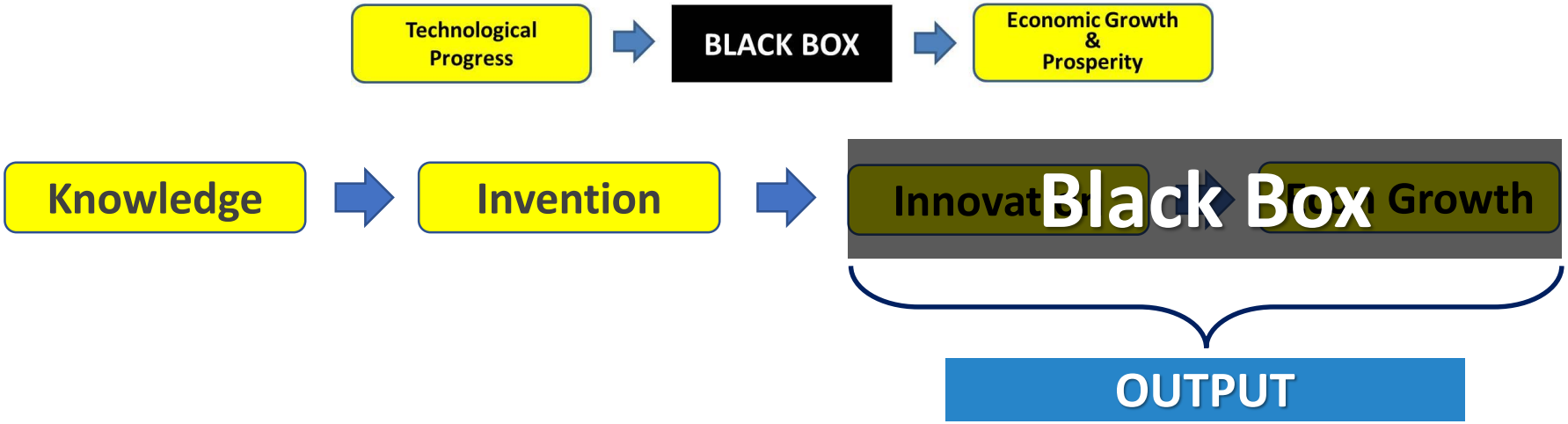
- **Knowledge production is a**
  - cumulative,
  - path-dependent, and
  - interactive process.

- **Knowledge [in] space**
  - Knowledge accumulates
  - Knowledge [type] relationships

- **Knowledge in the past**
  - provides opportunities, and sets limits
  - Entry, exit, selection



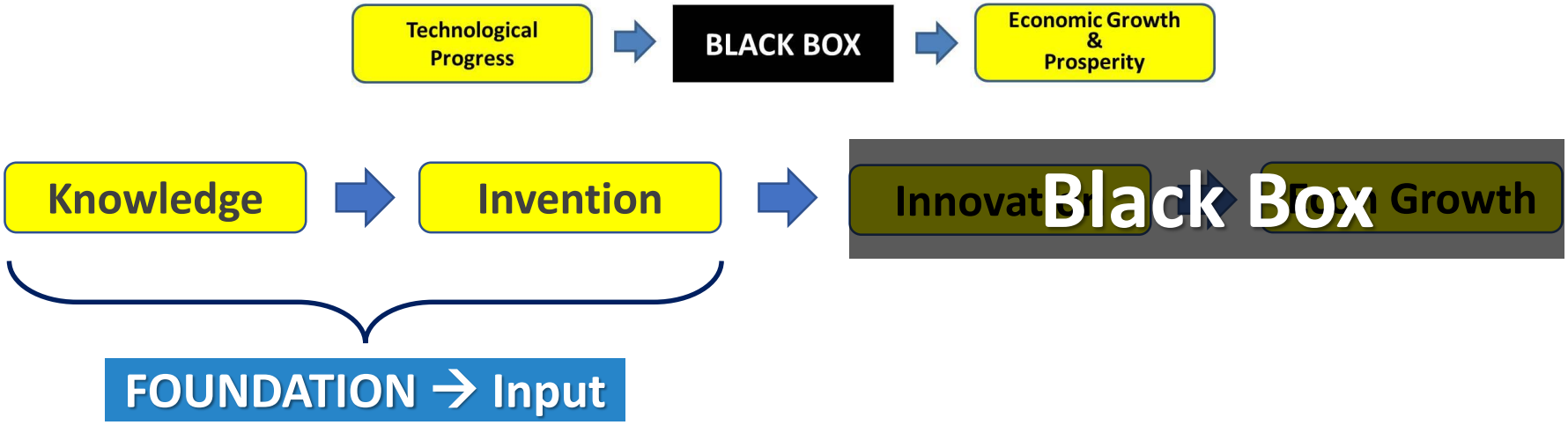
Stylized Concept of the 'Knowledge Economy'



- **Innovation is point of departure**
  (novel products and processes of economic value)
- **Productivity gains**
  (only one form of 'benefits'?)
- **Present "local" conditions**
  (spatial, social, sectoral, institutional, and organisational)

- **Micro/Macro structure**
  (division of actors → disciplines)
- **Dichotomous settings**
  (diversity vs specialisation or local vs global)
- **Post-evaluation**
  (static, or dynamic at best)

Stylized Concept of the 'Knowledge Economy'



- **Type of knowledge**
  scientific, technical, commercial
- **Evolution of knowledge**
  (overall & local)
- **Networks of production**
  (overall & local)
- **Specialization & cohesion**
  (place-specific)

- **Re-combination potential**
  (place-specific)
- **Nexus between individuals, firms, and place**
  (socio-spatial dialectic)
- **Life-cycles and path-creation**
  (path-dependency sets local limits and opportunities)

The Origin of Innovation? Recombination

To produce means to combine materials and forces within our reach ... To produce other things ... means to combine these materials and forces differently. (Schumpeter, 1934: 65)

Most innovations derive from a novel manner of…

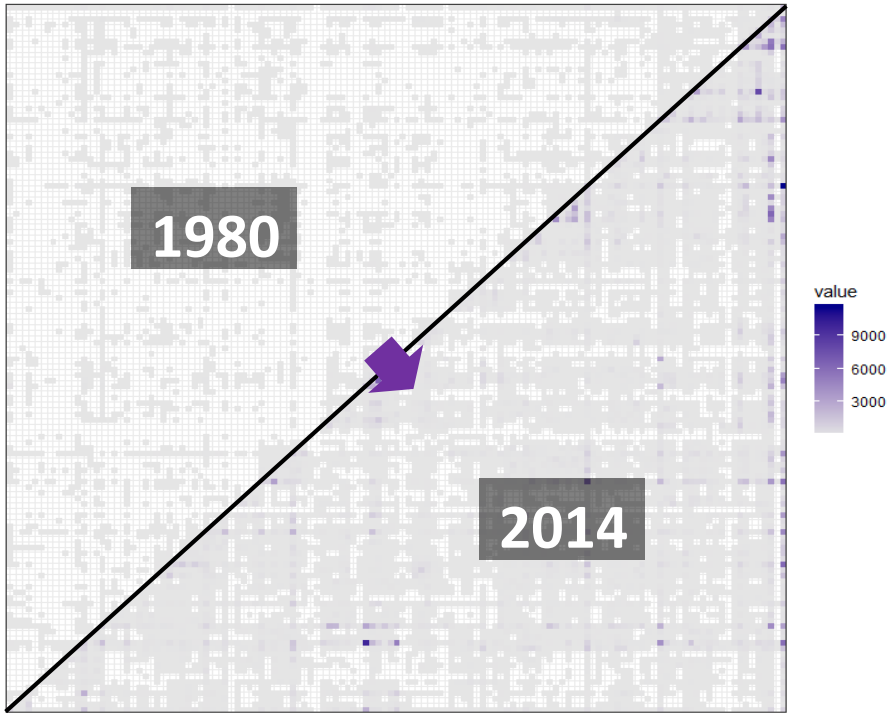
(1) combining existing technology
(Carnabuci and Bruggeman, 2009; Fleming, 2001; Nelson and Winter, 1982; Schumpeter, 1934)

→ **Exploration**

(2) improving existing technological combinations
(Henderson and Clark, 1990; Yayavaram and Ahuja, 2008)

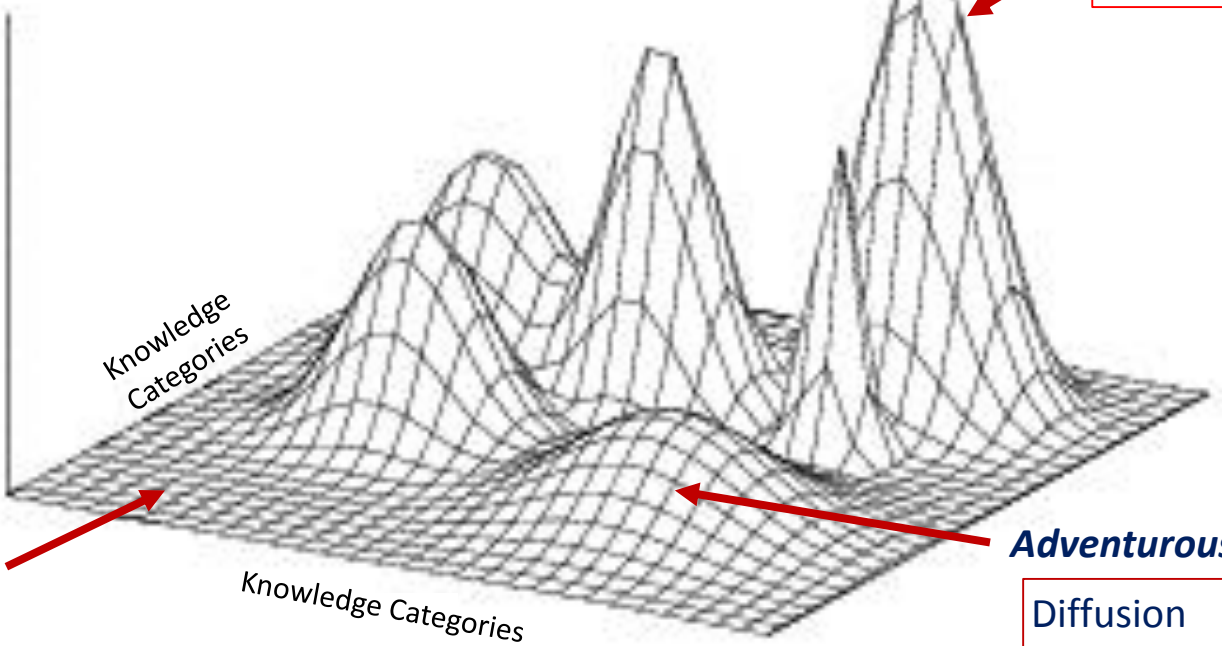
→ **Exploitation**

CPC Co-Occurrence Matrix



Source: PATSTAT, authors' own calculation

The Origin of Innovation? Recombination



Crowded Space

Productivity ↑
Potential ↓

"Crazy Space"

Potential ↑
Risk ↑

Breakthrough/ Disruptive Innovation?

Adventurous Space

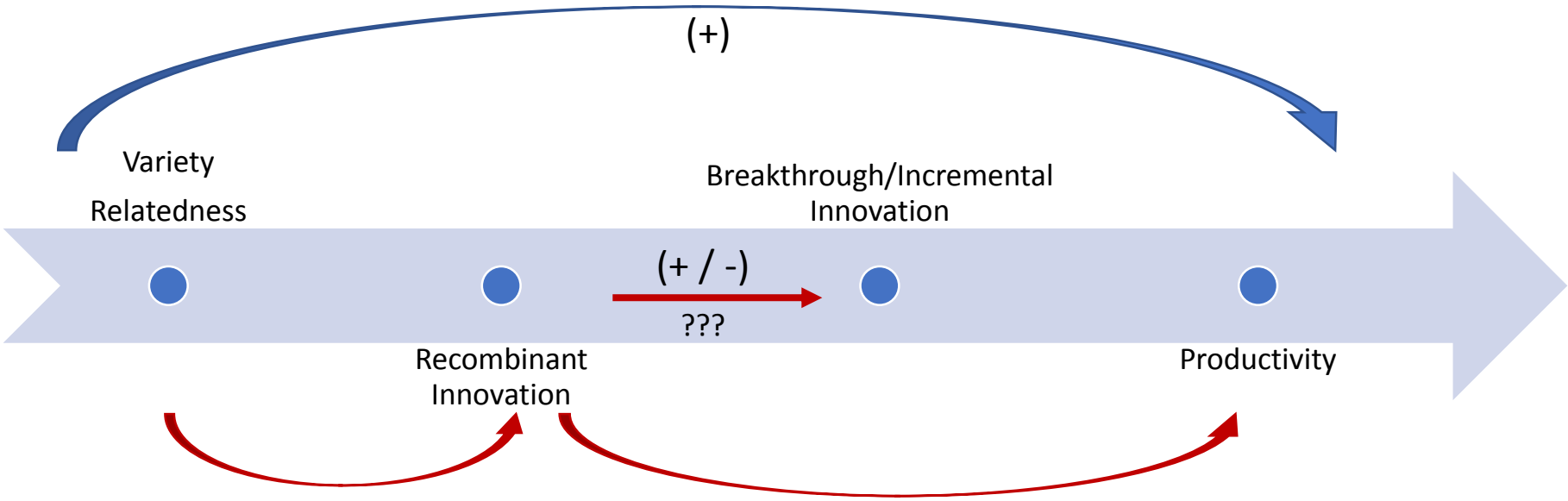
Diffusion ↑
Risk/Potential ≈

Incremental Innovation?

Knowledge Recombination "Search Space"

Knowledge Recombination and Regional Productivity

In EconGeo literature there's empirical evidence concerning this relationship, but many open questions remain…perhaps it needs a different approach!?



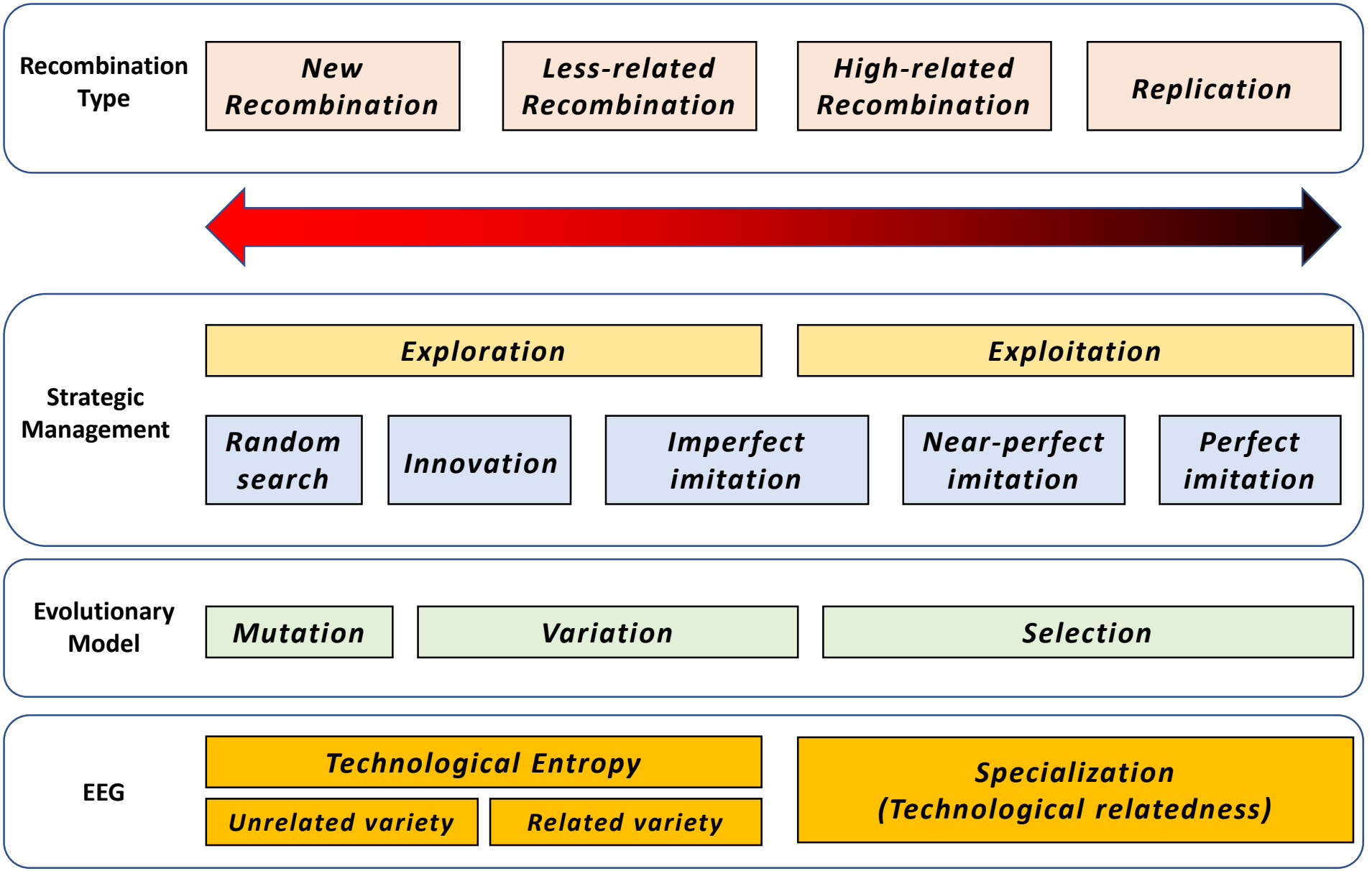
Research Gap #1

This paper is about that…

Research Gap #2

If you want to know more about this, get in touch with me…

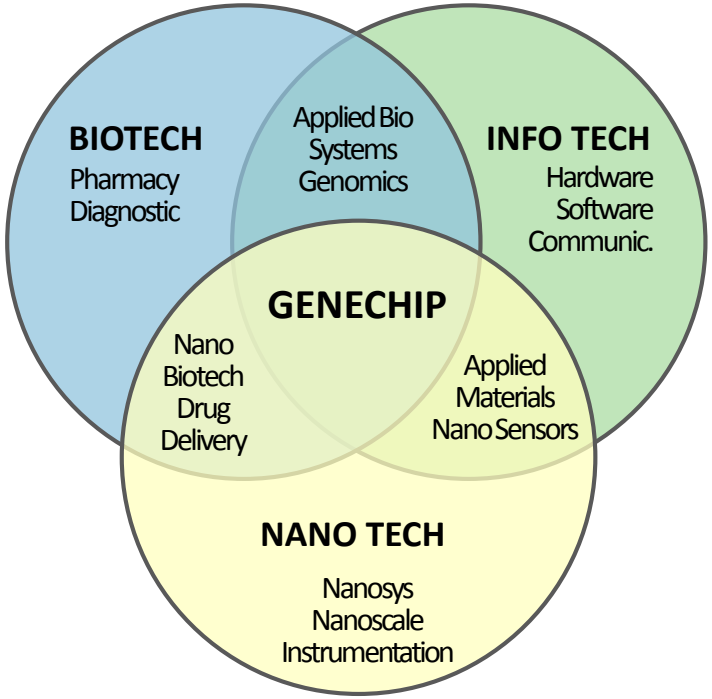
Theoretical Framing



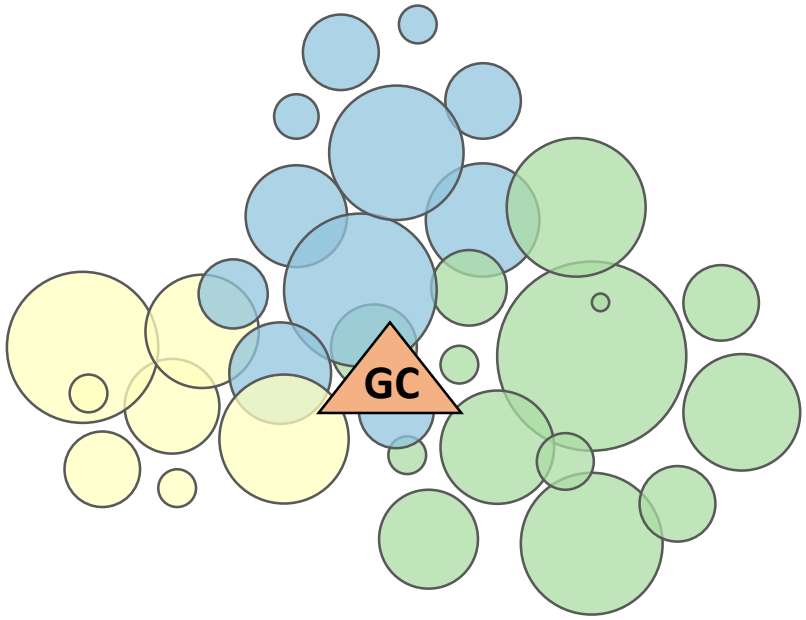
The Knowledge Space

Kogler et al. 2013, 2017

Economic Reality



Knowledge Space



Kogler D. F., Rigby D. L. & Tucker I. (2013) Mapping Knowledge Space and Technological Relatedness in US Cities, European Planning Studies.

EPO Patent Data – PATSTAT (1980-2014)

Patent Classification

Inventor(s)

Priority Date

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 711 947 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
26.03.2014 Bulletin 2014/13

(51) Int Cl.:
H01F 38/18 *(2006.01)* ***F03D 11/00*** *(2006.01)*
F03B 13/10 *(2006.01)* ***F03B 13/26*** *(2006.01)*

(21) Application number: **13182981.4**

(22) Date of filing: **04.09.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **24.09.2012 GB 201216961**
24.09.2012 GB 201216963

(71) Applicant: **Rolls-Royce plc**
London SW1E 6AT (GB)

(72) Inventors:
- **Anthony, John**
  Bishopsteignton Devon TQ14 9PS (GB)
- **Chong, Ellis**
  Derby DE23 3TU (GB)
- **Palethorpe, Benjamin**
  Nottingham Nottinghamshire NG7 5JH (GB)
- **Hartley, Andrew**
  Ashbourne Derbyshire DE6 2HB (GB)

(74) Representative: **Hartley, Andrew Colin et al**
Rolls-Royce plc
SinB-38, P.O. Box 31
Derby DE24 8BJ (GB)

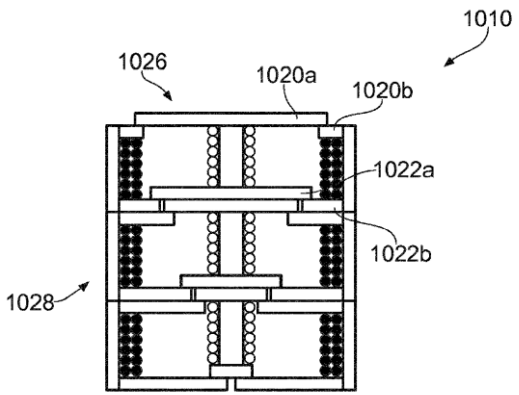


FIG. 10

(54) **A power transfer device**

(57) Described is an electrical power transfer device for transferring power between two coaxial relatively rotatable components, comprising: an outer core having a magnetic flux guide, an outer electrical winding and a cavity for receiving an inner core; an inner core located at least partially within the cavity, the inner core having a magnetic flux guide and an inner winding, wherein the inner and outer core are arranged to be movable between a first configuration in which the magnetic flux guides of the inner and outer cores separated by a first distance in which power is transferred in use, and a second configuration in which the inner and outer cores are separated by a second distance, in which relative rotation of the inner and outer cores is possible in the second configuration, wherein in the first configuration the magnetic flux guides of the inner and outer cores abut one another.

Categorizing Knowledge – Patent Classes

Cooperative Patent Classification (CPC)

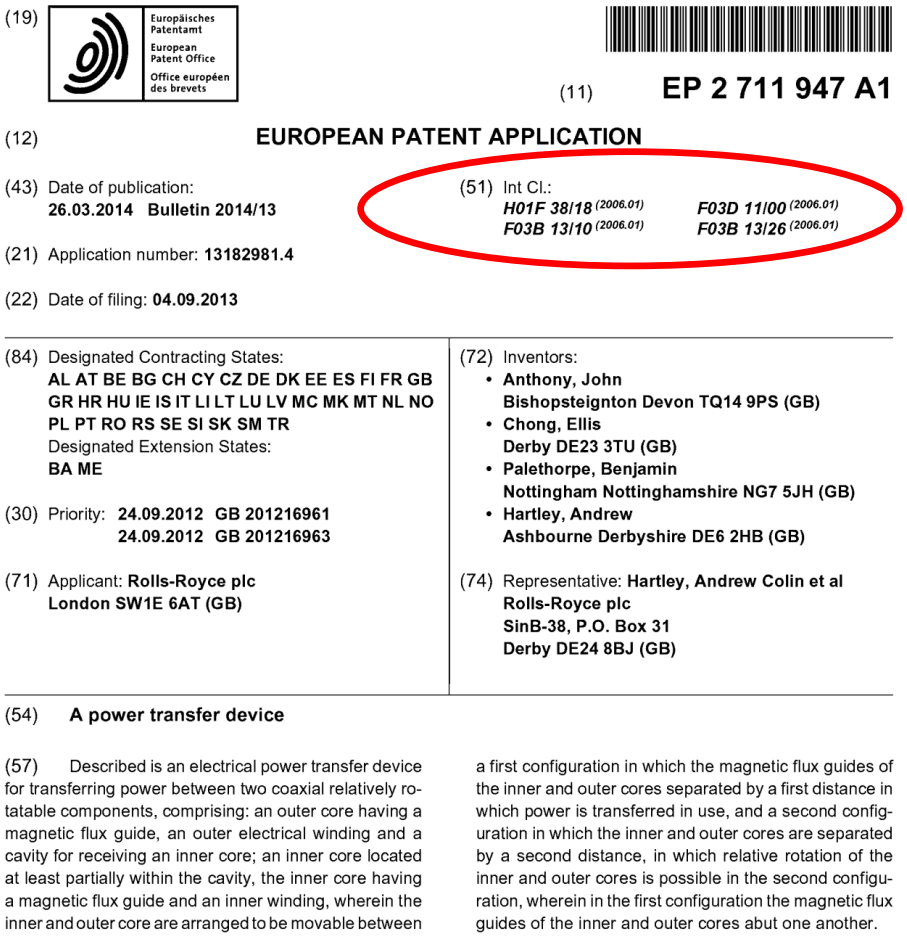
(1,3,4 and more digits…)

- Chemistry and Metallurgy
- Electricity
- Textiles, Paper
- New, Cross-over Technologies
- Construction
- Physics
- Transport and Operations
- Consumer goods
- Mechanical Engineering

1-Digit Level:

F Mechanical engineering

H Electricity



(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 2 711 947 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.03.2014 Bulletin 2014/13

(51) Int Cl.:
H01F 38/18 *(2006.01)* ***F03D 11/00*** *(2006.01)*
F03B 13/10 *(2006.01)* ***F03B 13/26*** *(2006.01)*

(21) Application number: **13182981.4**

(22) Date of filing: **04.09.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **24.09.2012 GB 201216961**
24.09.2012 GB 201216963

(71) Applicant: **Rolls-Royce plc**
London SW1E 6AT (GB)

(72) Inventors:
- **Anthony, John**
  Bishopsteignton Devon TQ14 9PS (GB)
- **Chong, Ellis**
  Derby DE23 3TU (GB)
- **Palethorpe, Benjamin**
  Nottingham Nottinghamshire NG7 5JH (GB)
- **Hartley, Andrew**
  Ashbourne Derbyshire DE6 2HB (GB)

(74) Representative: **Hartley, Andrew Colin et al**
Rolls-Royce plc
SinB-38, P.O. Box 31
Derby DE24 8BJ (GB)

(54) **A power transfer device**

(57) Described is an electrical power transfer device for transferring power between two coaxial relatively rotatable components, comprising: an outer core having a magnetic flux guide, an outer electrical winding and a cavity for receiving an inner core; an inner core located at least partially within the cavity, the inner core having a magnetic flux guide and an inner winding, wherein the inner and outer core are arranged to be movable between a first configuration in which the magnetic flux guides of the inner and outer cores separated by a first distance in which power is transferred in use, and a second configuration in which the inner and outer cores are separated by a second distance, in which relative rotation of the inner and outer cores is possible in the second configuration, wherein in the first configuration the magnetic flux guides of the inner and outer cores abut one another.

3 & 4-Digit Level:

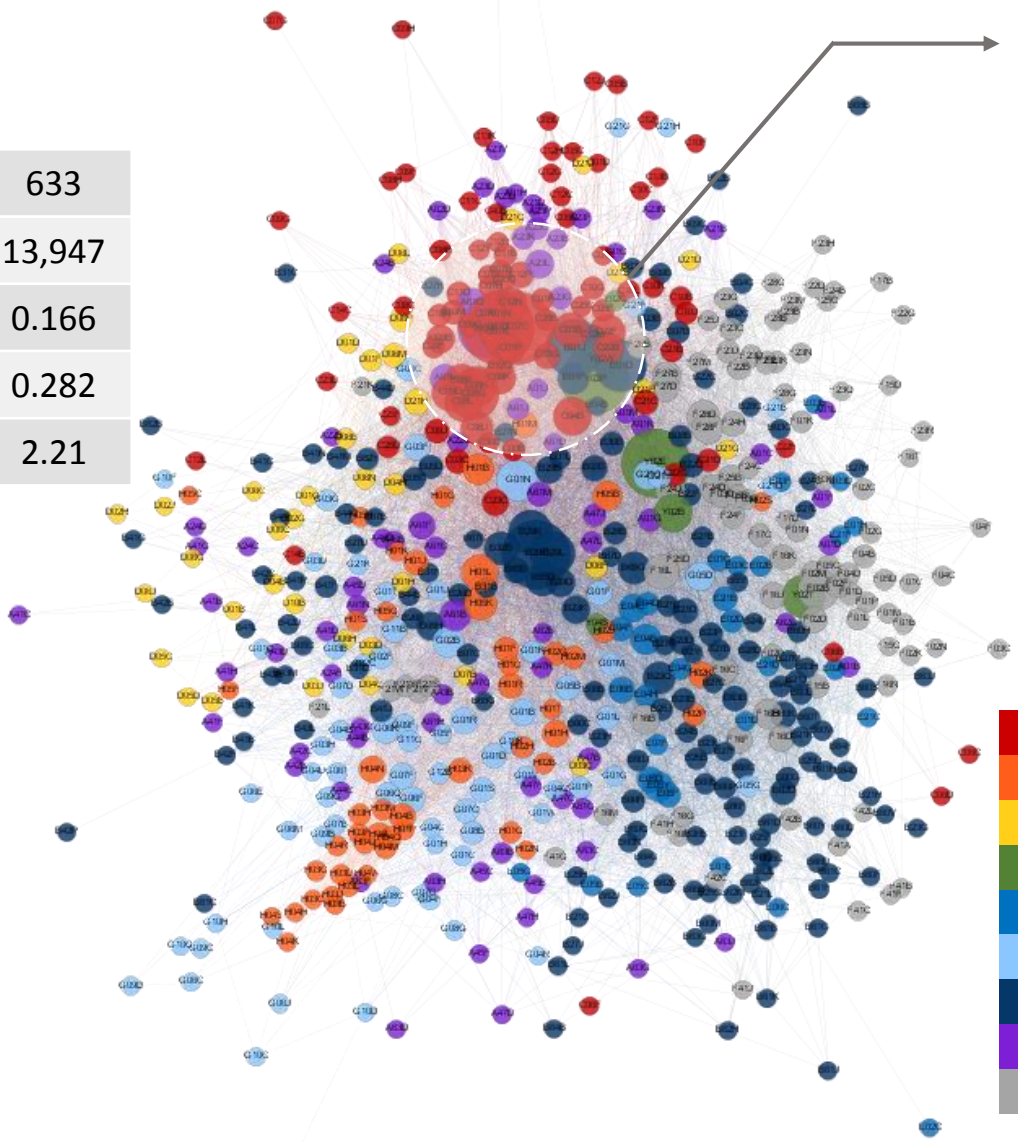
F03 MACHINES OR ENGINES FOR LIQUIDS; WIND, SPRING, OR WEIGHT MOTORS; PRODUCING MECHANICAL POWER OR A REACTIVE PROPULSIVE THRUST, NOT OTHERWISE PROVIDED FOR

F03B MACHINES OR ENGINES FOR LIQUIDS

EU Knowledge Space Evolution and Recombination Hotspots

(1980-1984)

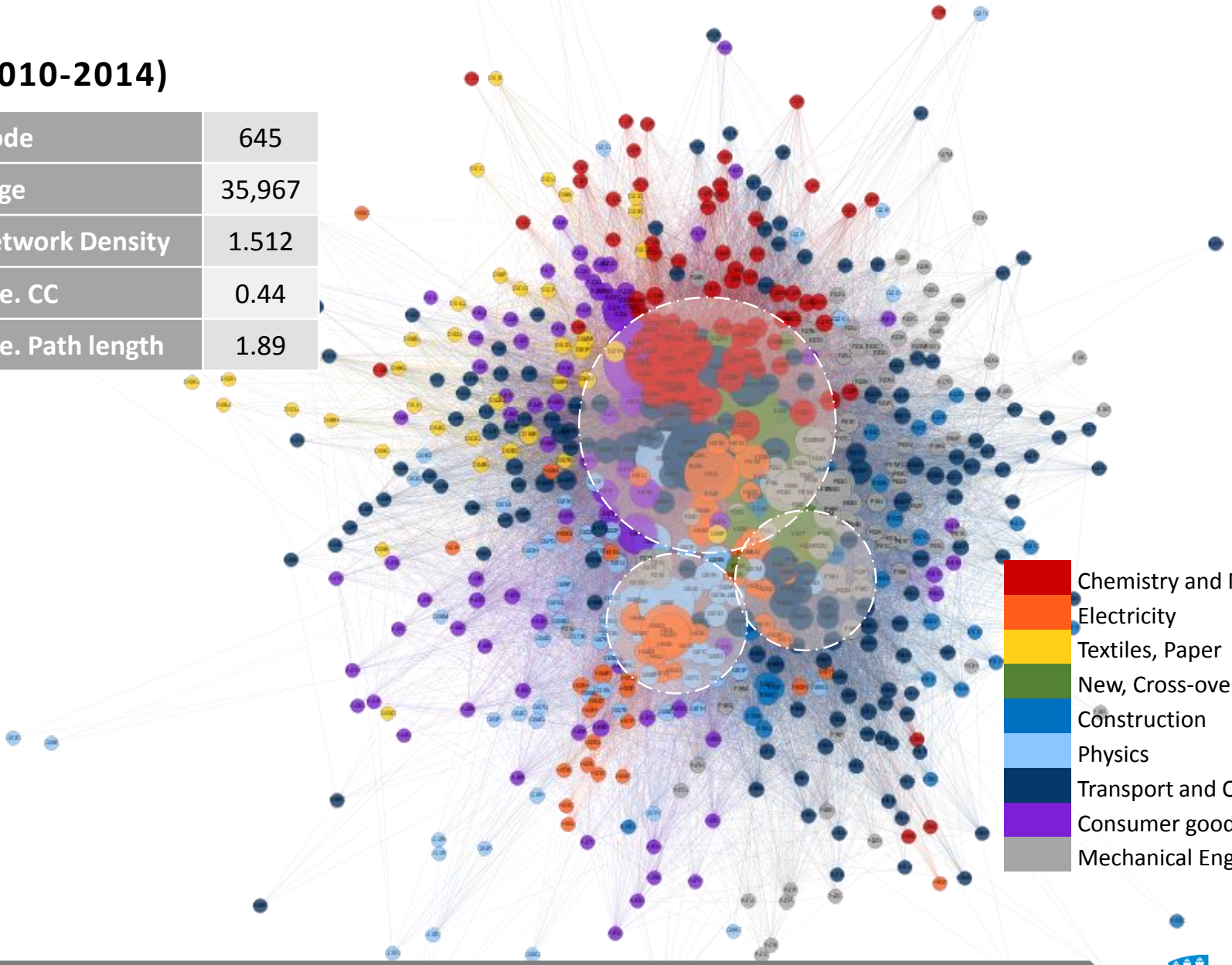
Node	633
Edge	13,947
Network Density	0.166
Ave. CC	0.282
Ave. Path length	2.21



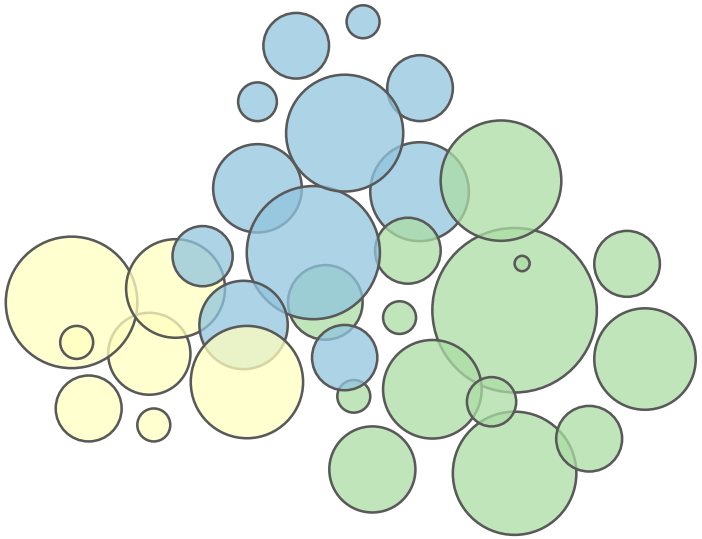
EU Knowledge Space Evolution and Recombination Hotspots

(2010-2014)

Node	645
Edge	35,967
Network Density	1.512
Ave. CC	0.44
Ave. Path length	1.89



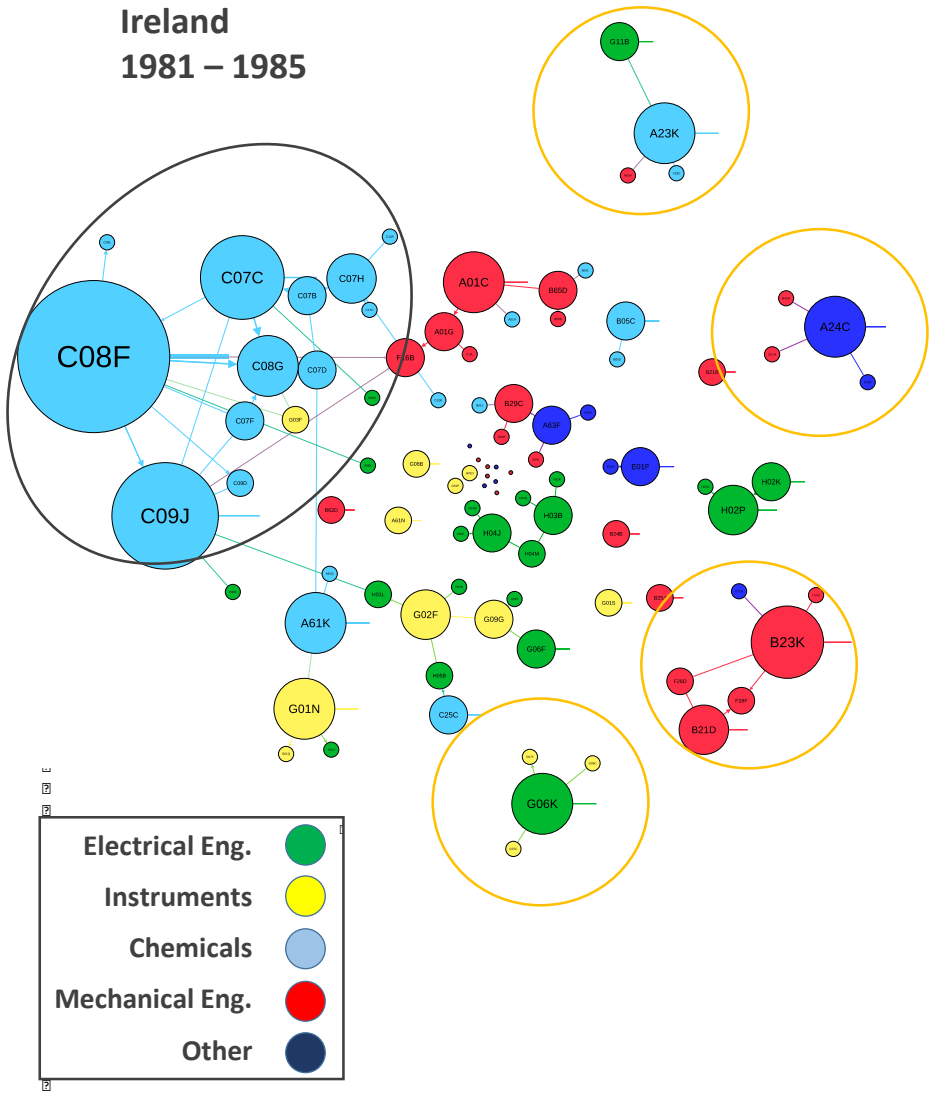
The Evolution of the Irish Knowledge Space



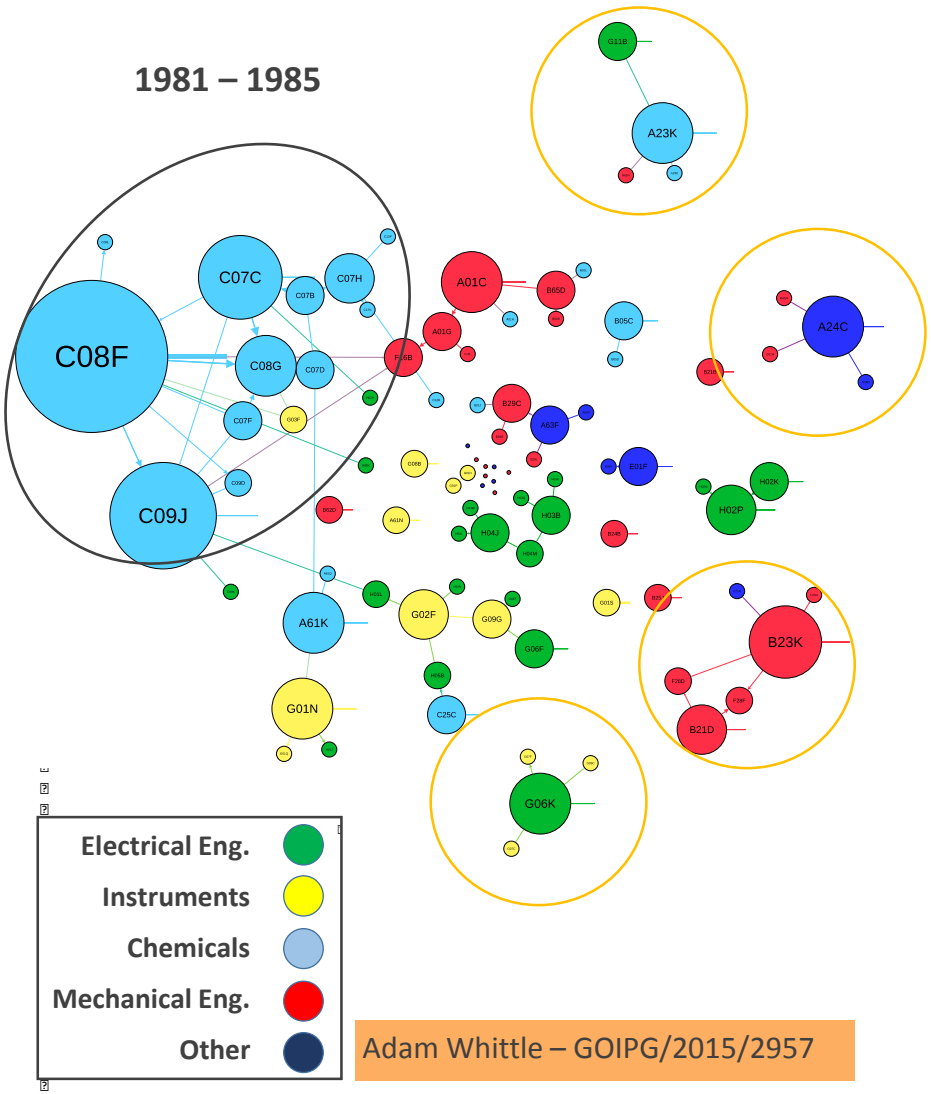
Co-occurrence matrix of IPC codes

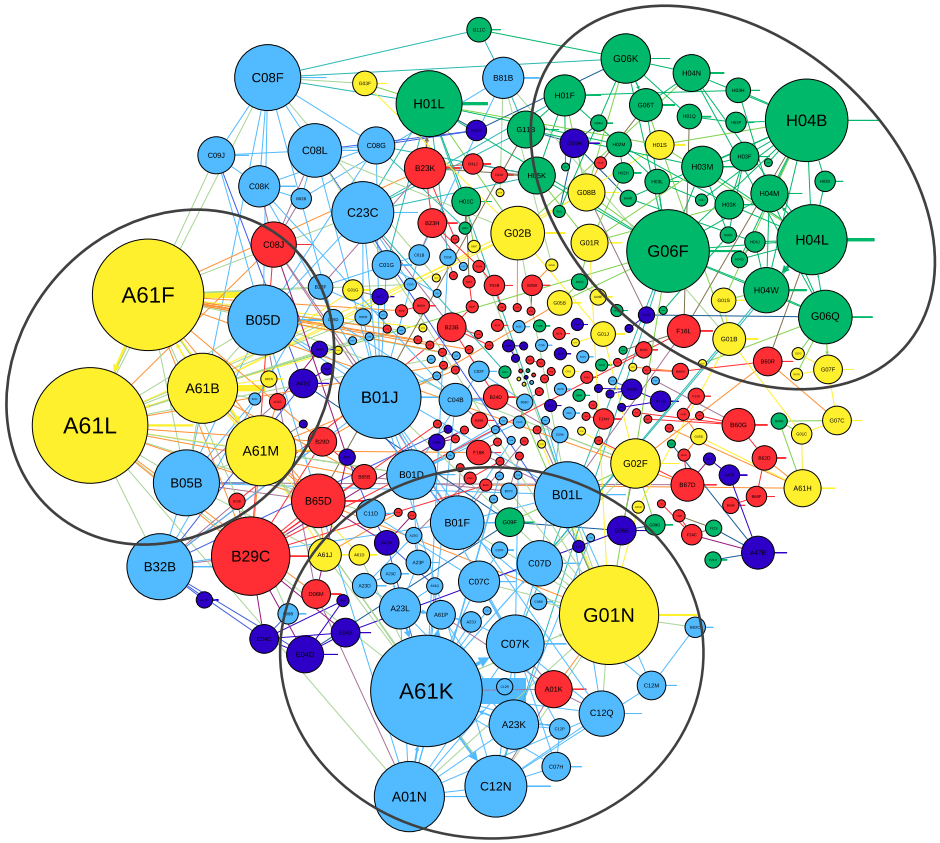
	IT01	IT02	IT03	BIO01	BIO02	BIO03	NT01	NT02	NT03
IT01									
IT02									
IT03									
BIO01									
BIO02									
BIO03									
NT01									
NT02									
NT03									

Ireland
1981 – 1985



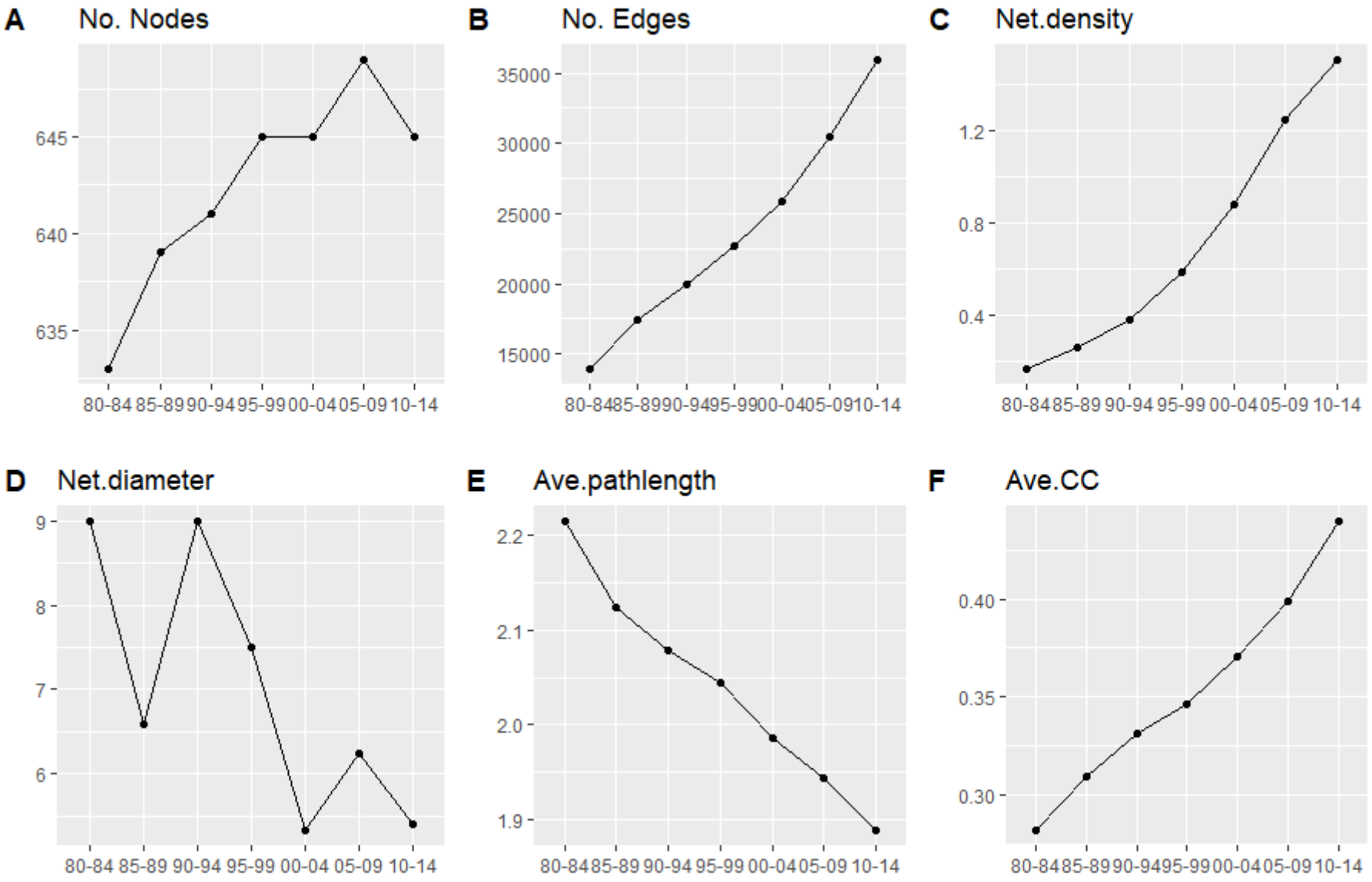
The Evolution of the Irish Knowledge Space





Adam Whittle – GOIPG/2015/2957

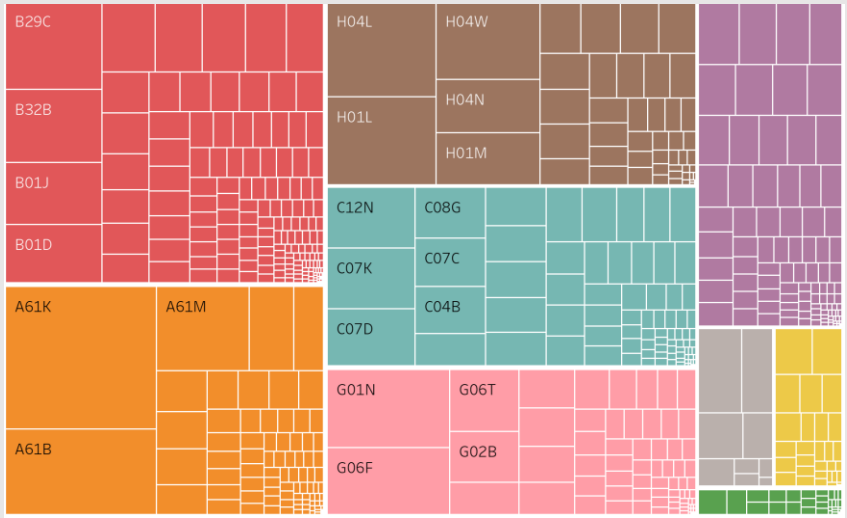
EU Knowledge Space Evolution – Network Measures



Local Knowledge Spaces – Two Dimensions

Two Relevant Dimensions in Local KS: **Composition of Nodes & Connectivity**

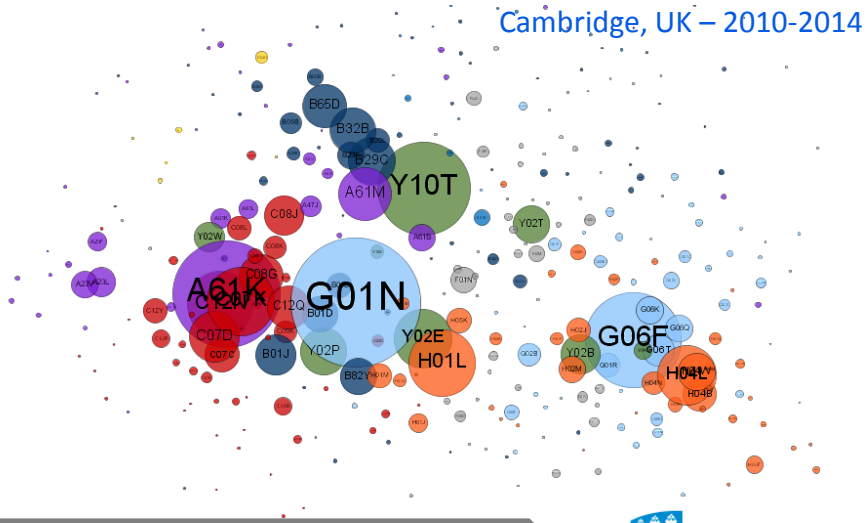
Composition of local technology portfolio



Technology Portfolio Dimension

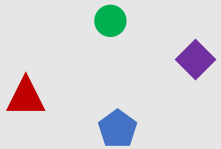
Knowledge Space Dimension

Local Technology Co-Occurrence Network

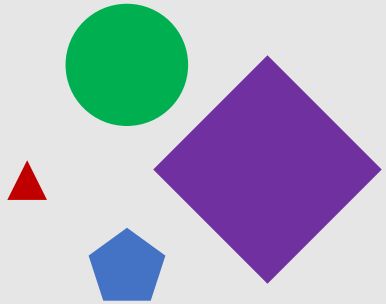


Local Knowledge Structure – Four Dimensions?!

Two Dimensions become Four Dimensions…



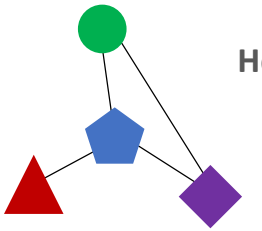
How many



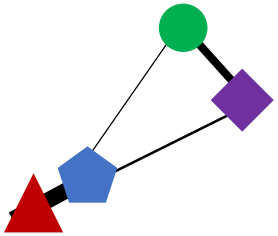
How evenly

Technology Portfolio Dimension (Node dimension)

Knowledge Space Dimension (Edge dimension)



How densely

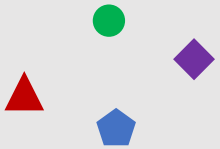


How related

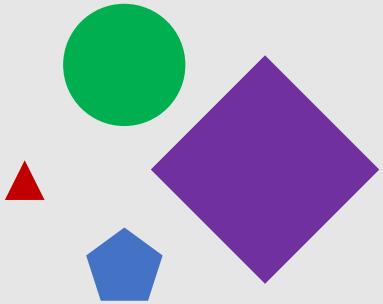
Local Knowledge Structure – Four Dimensions?!

Measurements

Technology Pool
The number of unique CPC codes found in the local portfolio

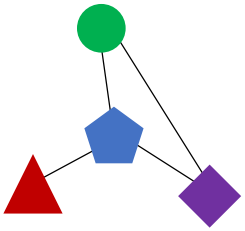


Technology Portfolio Dimension (Node dimension)



Entropy of CPC codes in the local technology portfolio

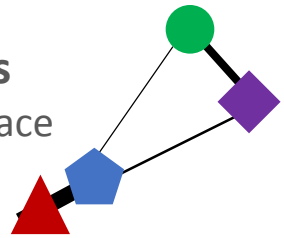
Knowledge Space Dimension (Edge dimension)



Recombinant Density
Network density in the local knowledge space

The proportion of direct ties in a network relative to the total number possible

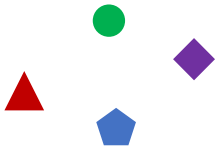
Average Relatedness
in the local knowledge space



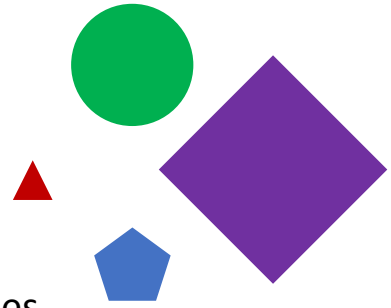
Total technology relatedness based on the universal (EU) knowledge space

Balance and Synergies Among Dimensions

Node dimension: Quantity and Distribution of Building Blocks



Technology Pool
The number of unique CPC codes found in the local portfolio



Entropy of CPC codes in the local technology portfolio

- Quantity is a necessary first condition for possibly generating new recombinant knowledge!
  - *…good **Selection** is made in high **Diversity**…(well-known fact in evolutionary biology)*
  - **Variety** (Related or Unrelated) in a region supports the entry into new recombinant knowledge spaces

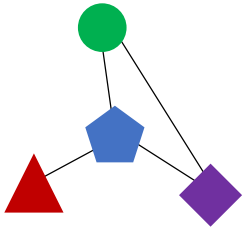
Balance and Synergies Among Dimensions

Edge dimension: Density and Relatedness of Building Blocks

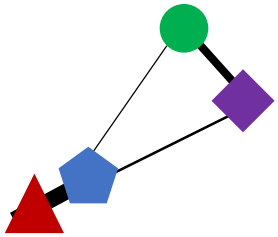
- The connection of nodes previously unconnected results in novel knowledge recombinations
  - Recombinant knowledge occurs frequently among technologies that exhibit **high proximity** to each other
  - **High density** boosts probability to combine existing technologies and create a new one

---

Recombinant Density
Network density in the local knowledge space



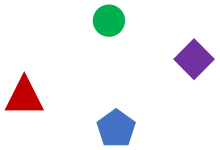
Average Relatedness
in the local knowledge space

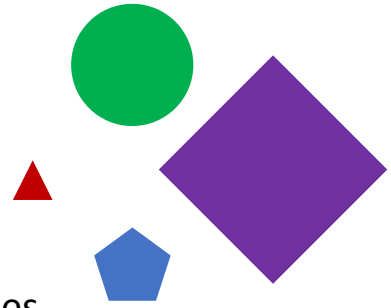


Balance and Synergies Among Dimensions

Both dimensions are important, but..

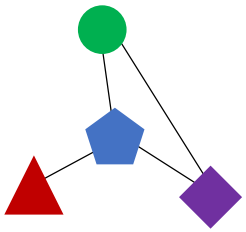
Technology Pool
The number of unique CPC codes found in the local portfolio

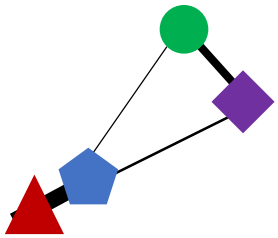




Entropy of CPC codes in the local technology portfolio

Recombinant Density
Network density in the local knowledge space

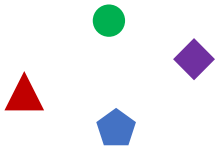




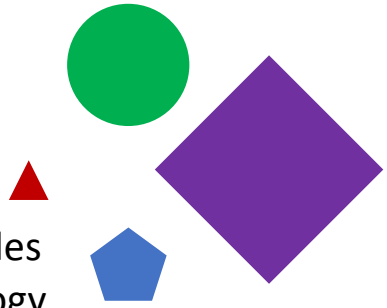
Average Relatedness
in the local knowledge space

Balance and Synergies Among Dimensions

…the **balance** between node and edge dimensions should be most efficient!

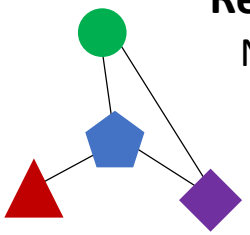


Technology Pool
The number of unique CPC codes found in the local portfolio

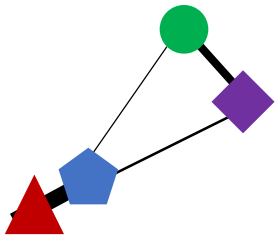


Entropy of CPC codes in the local technology portfolio

Balance!



Recombinant Density
Network density in the local knowledge space



Average Relatedness
in the local knowledge space

NUTS3 & Metropolitan Regions

1,387 NUTS 3 (2013) Regions in EU 28 + 2

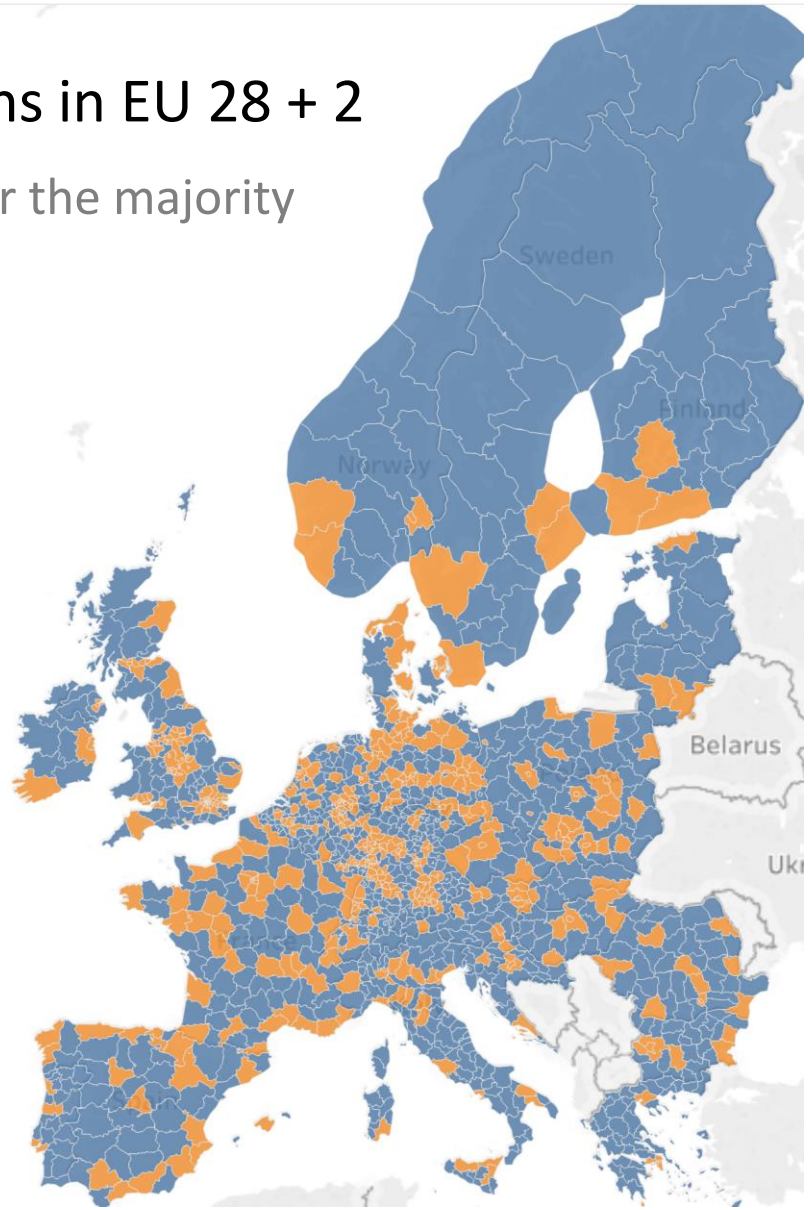
→ Not the most suitable scale for the majority of socio-economic analysis!

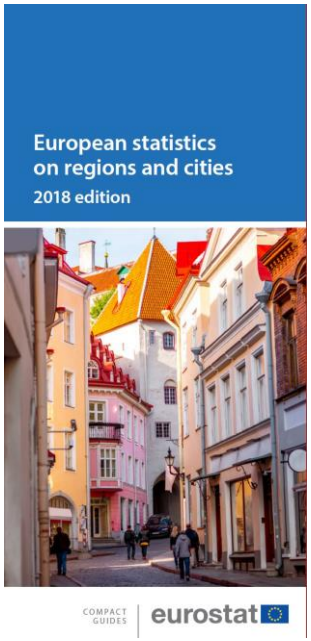
Example – London UK:
20 NUTS 3 & 3 NUTS 2 Regions

Reclassification into
1,123 Regions

274 Metro-Regions
849 Non-Metro Regions

→ These 1,123 regions are suitable for most socio-economic analysis!





Novel Regional Recombinations – Modelling Approach

Linear Mixed Model with Time and Regional Fixed Effects, and Country Random Effects

Model 1. **New Recombinations – Relatedness & Entropy**

$$Y_{ijt} = \beta_0 + \beta_1 Entropy_{ijt} + \beta_2 Relatedness_{ijt} + \beta_3 (Entropy_{ijt} \times Relatedness_{ijt}) + \boldsymbol{\beta_4 X_{ijt}} + \boldsymbol{\beta_5 Year.FE_t} + \boldsymbol{\beta_6 Regional.FE_{ij}} + \mu_{ij} + \varepsilon_{\boldsymbol{ijt}}$$

Model 2. **New Recombinations – Entropy & Density**

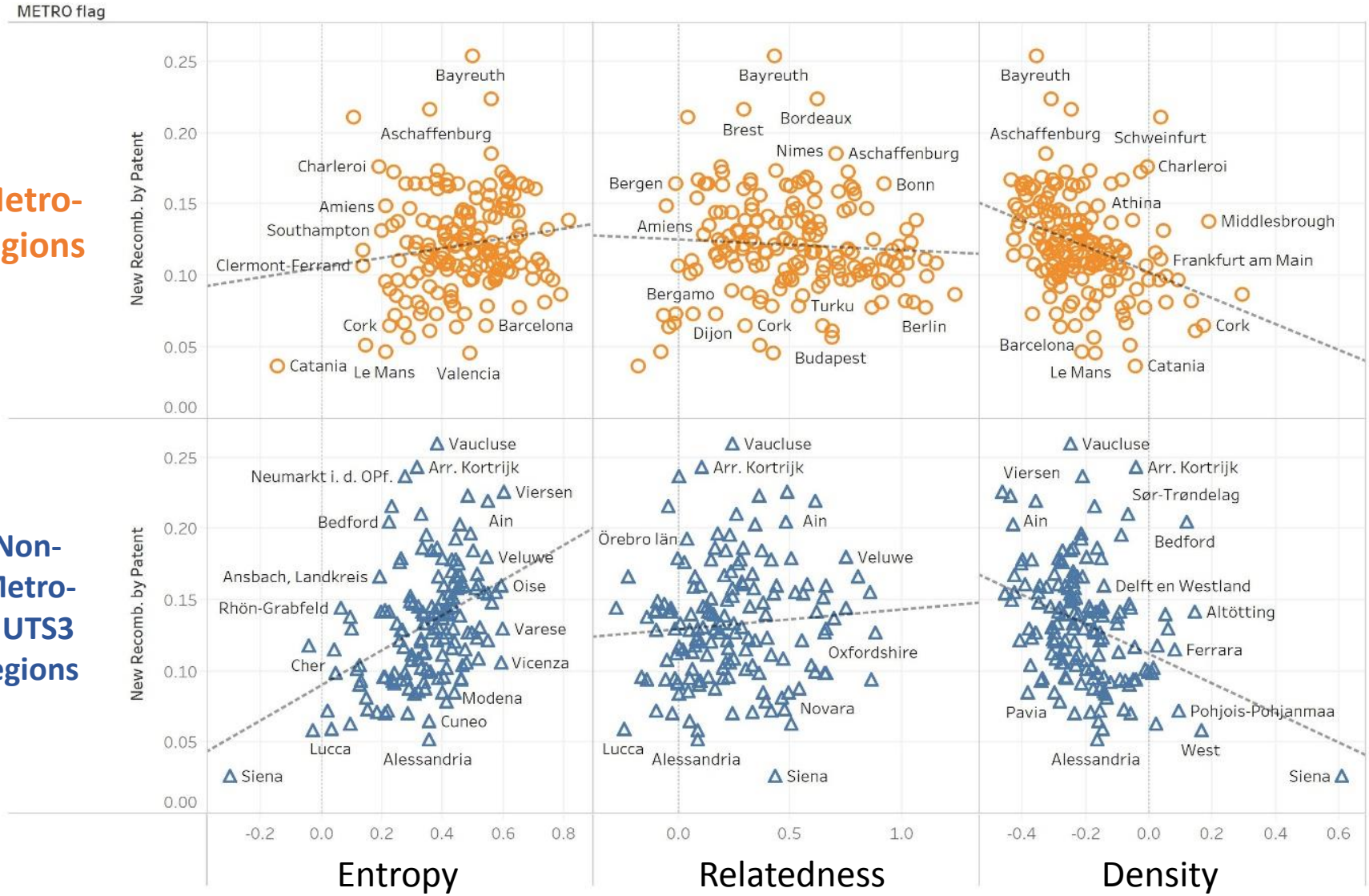
$$Y_{ijt} = \beta_0 + \beta_1 Entropy_{ijt} + \beta_2 Density_{ijt} + \beta_3 (Entropy_{ijt} \times Density_{ijt}) + \boldsymbol{\beta_4 X_{ijt}} + \boldsymbol{\beta_5 Year.FE_t} + \boldsymbol{\beta_6 Regional.FE_{ij}} + \mu_{ij} + \varepsilon_{\boldsymbol{ijt}}$$

Model 3. **New Recombinations – Density & Relatedness**

$$Y_{it} = \beta_0 + \beta_1 Density_{it} + \beta_2 Relatedness_{it} + \beta_3 (Density_{it} \times Relatedness_{it}) + \boldsymbol{\beta_4 X_{ijt}} + \boldsymbol{\beta_5 Year.FE_t} + \boldsymbol{\beta_6 Regional.FE_{ij}} + \mu_{ij} + \varepsilon_{\boldsymbol{ijt}}$$

Descriptive Statistics I

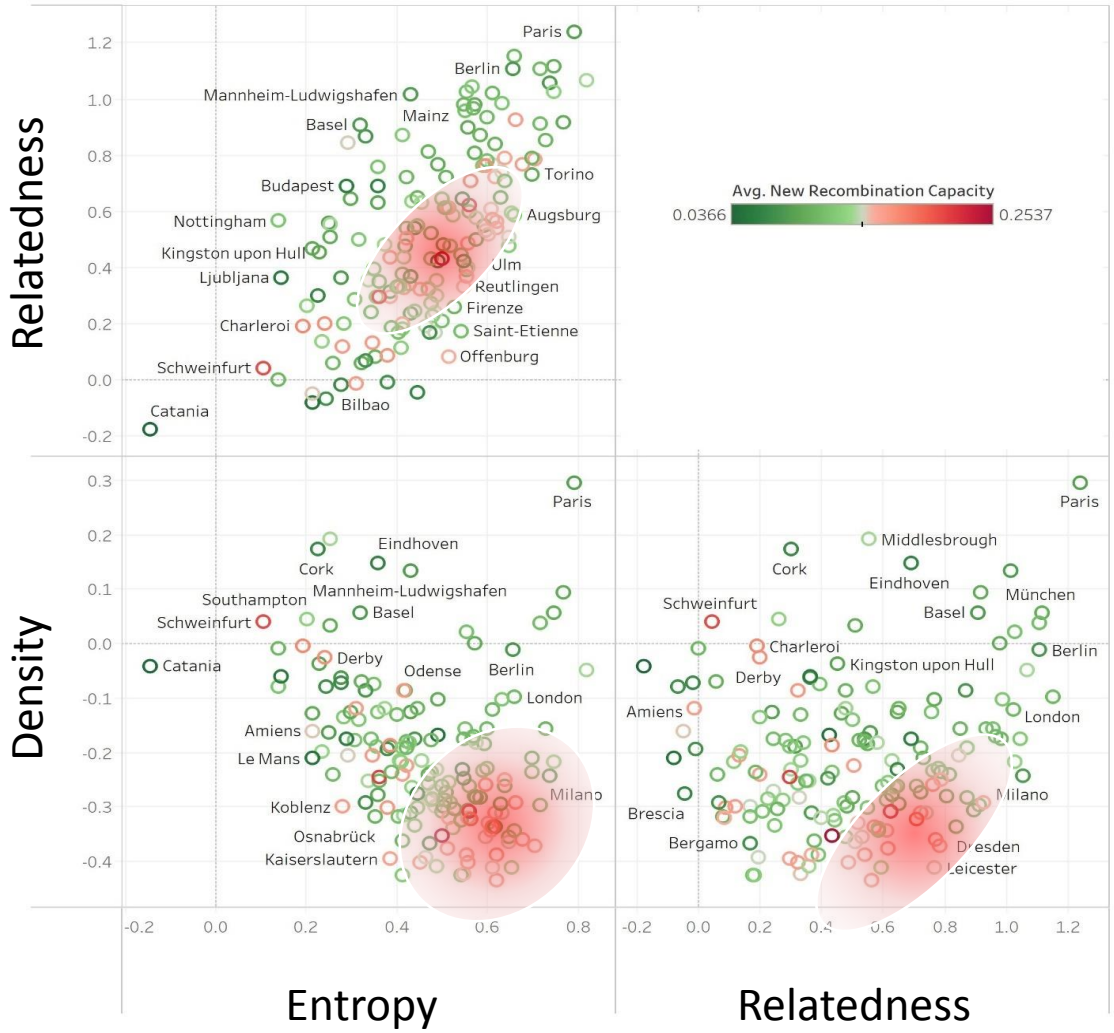
Correlation between independent variables (Entropy, Relatedness, and Density) and regional knowledge recombination capabilities.



Descriptive Statistics II

Density in the regional capacity of generating new recombinations among the node and edge dimensions (metro-city regions)

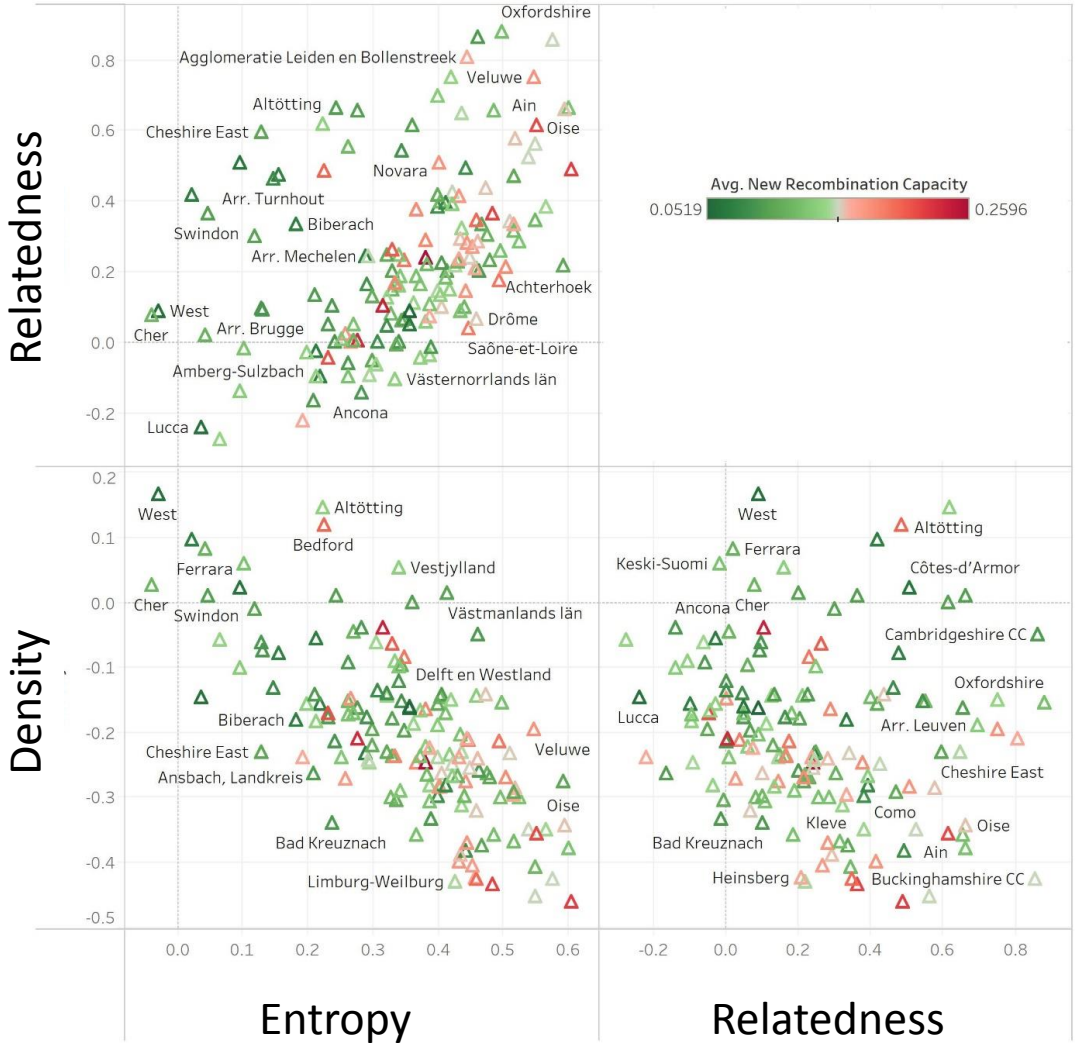
Metro-regions



Descriptive Statistics III

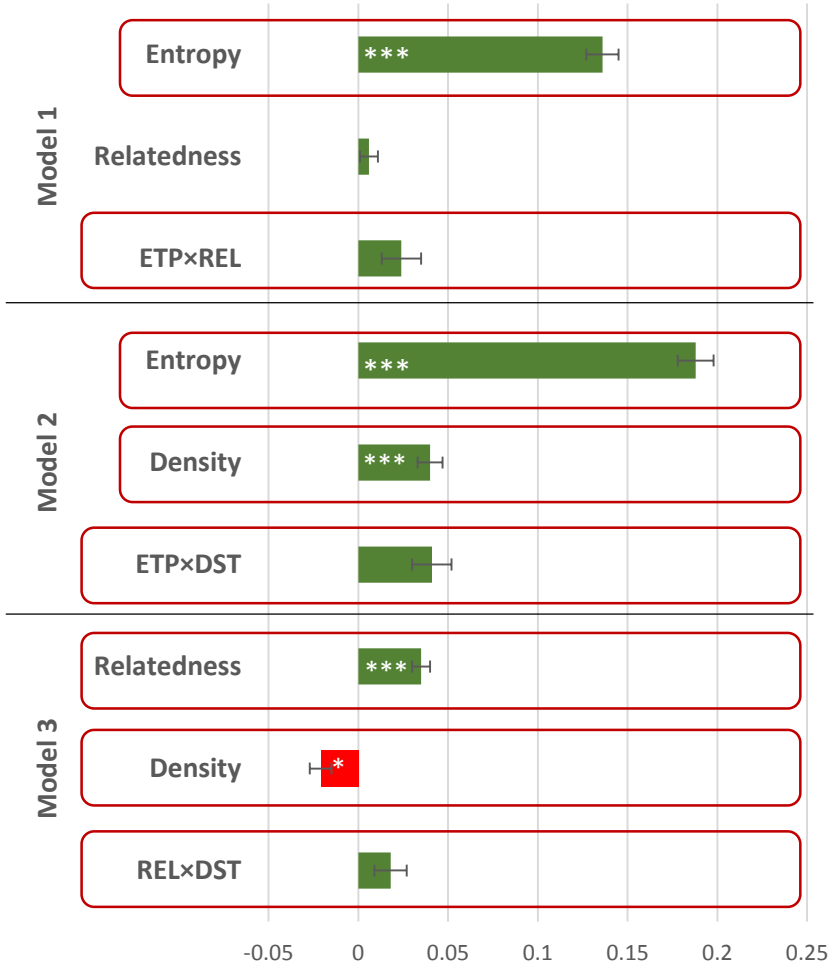
Density in the regional capacity of generating new recombinations among the node and edge dimensions (non-Metro NUTS III regions)

Non-Metro NUTS3 regions

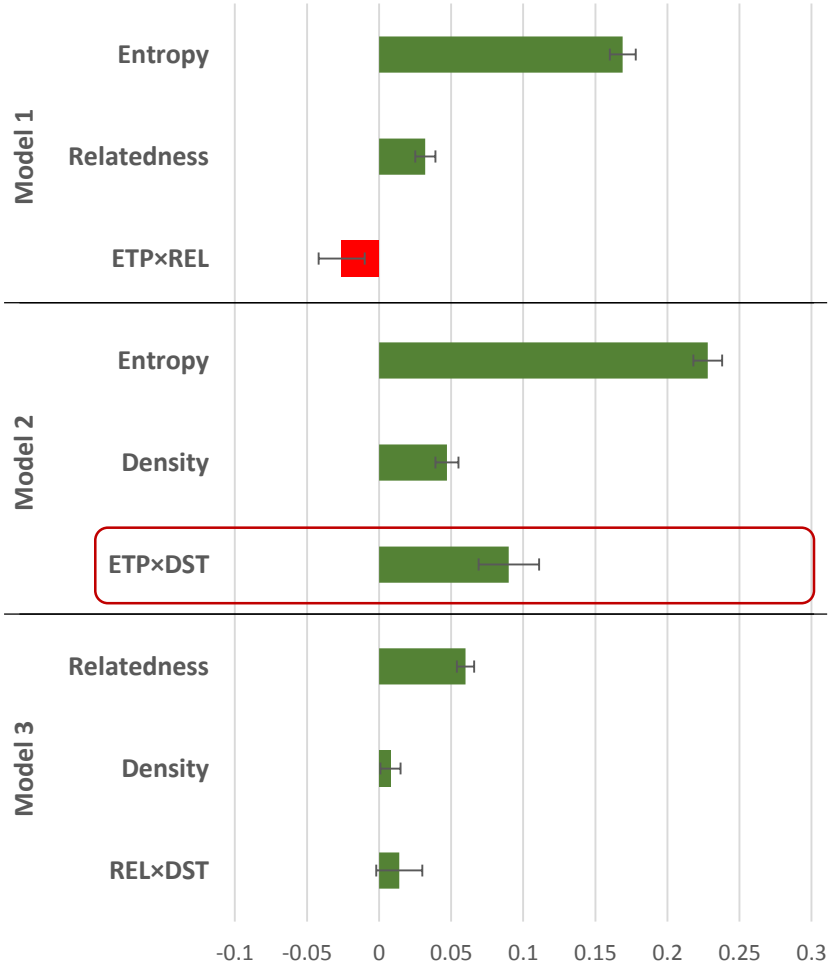


RESULTS (Coefficients and S.E.s in Regression Models)

Metro-city regions

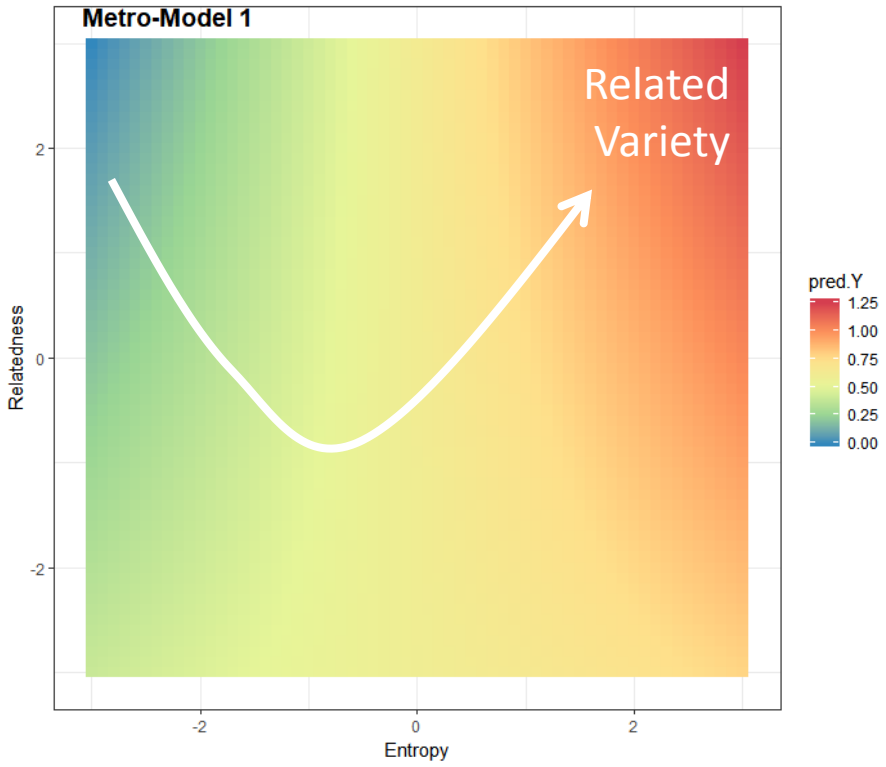


Non-Metro NUTS III regions

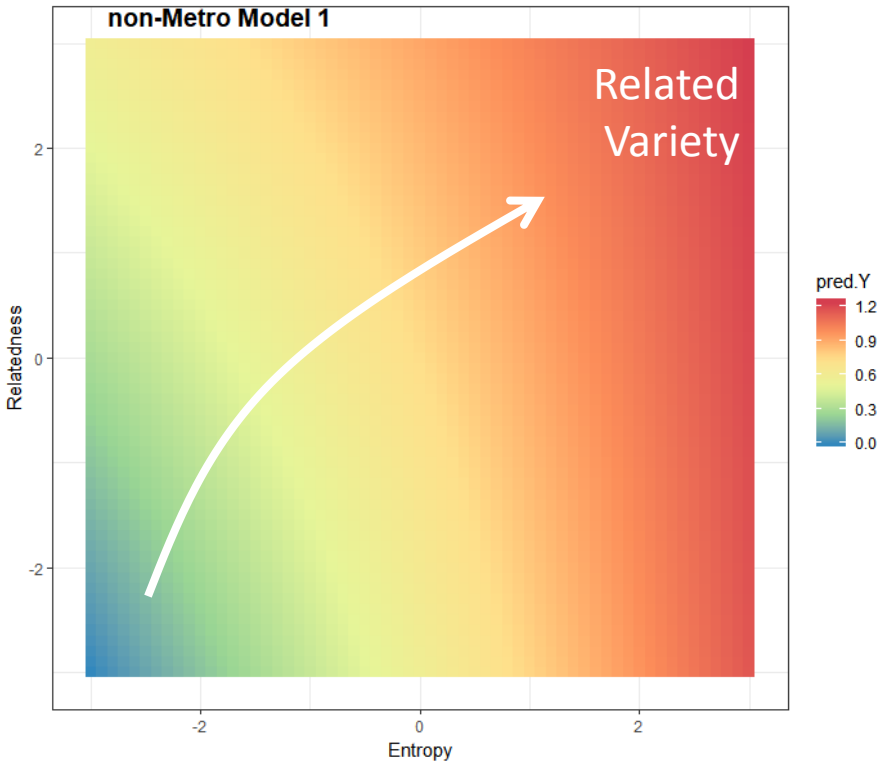


Model 1: Entropy & Relatedness

Metro-city regions

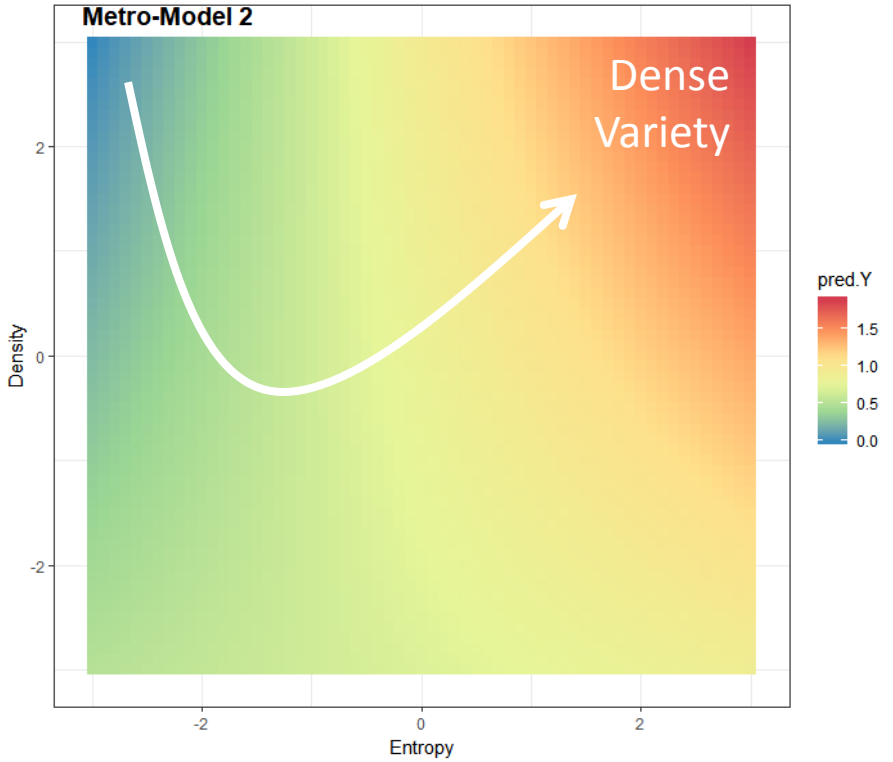


Non-Metro NUTS III regions

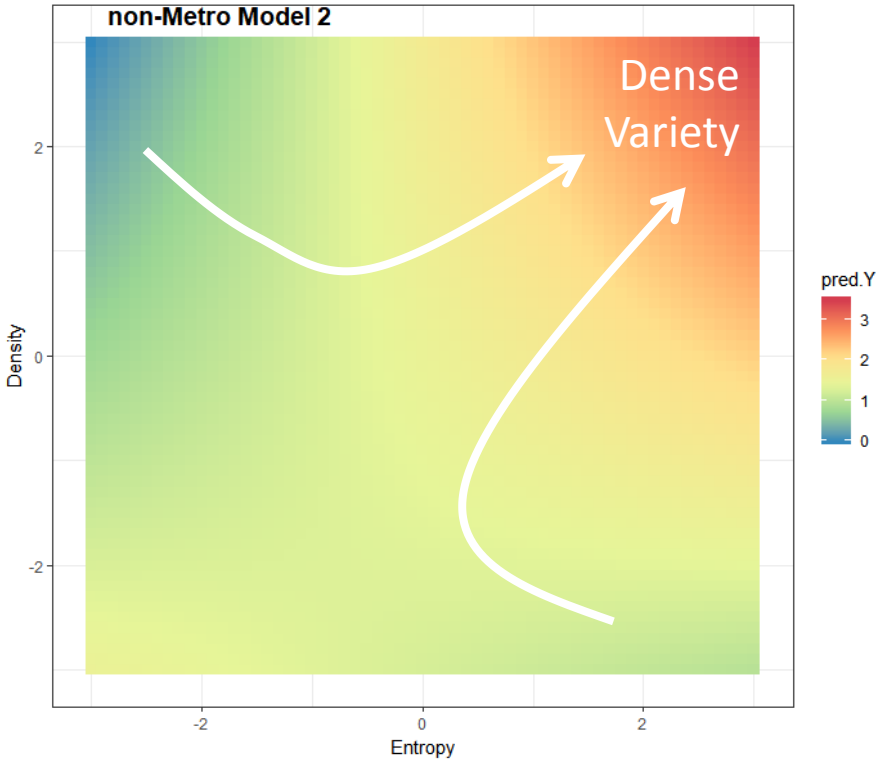


Model 2: Entropy & Density

Metro-city regions

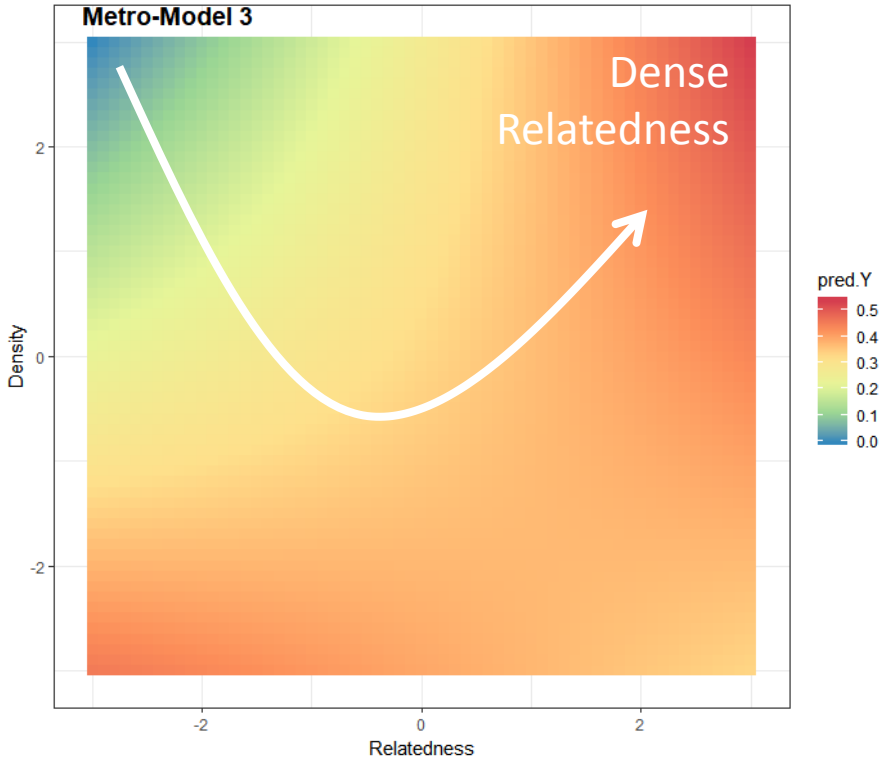


Non-Metro NUTS III regions

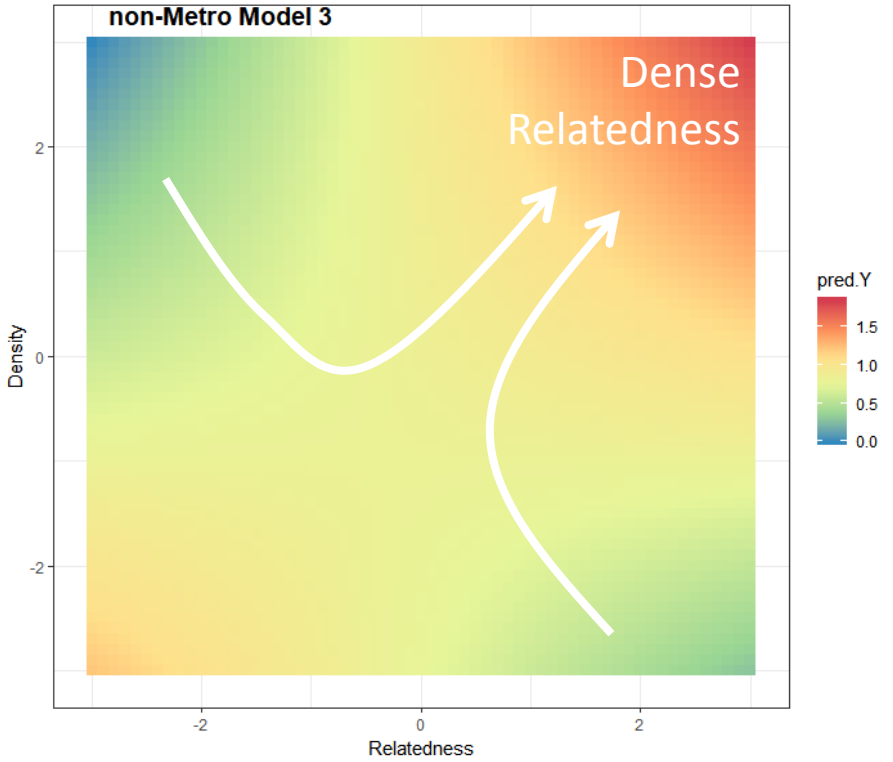


Model 3: Relatedness & Density

Metro-city regions



Non-Metro NUTS III regions



Discussion

- The Importance of the **Node Dimension:**
  - High Entropy and a large/wide pool of available technological knowledge is beneficial in any stage of the technology development process
  - Entropy is completed by Relatedness (**high Related Variety**)

- The **Edge Dimension** gains importance once enough diversity is achieved:
  - Entropy is ideally complemented by Density (**high Dense Variety**) in generating regional recombinant capacity
  - Relatedness is preferably also complemented by Density (**high Related Density** or **Dense Relatedness**)

Take-Home Message…Policy Implications?!

- **The evolutionary trajectory of novel knowledge production**:
  Node → Edge dimensional extension
  - Node extension: a mandatory condition
  - Edge extension: will boost the creation of new recombinant knowledge

---

Knowledge-based and knowledge-driven **economic development** might be a **two stage-process**. Pending on the developmental stage of a given locality, perhaps initial focus needs to be on increasing diversity (Jacobian-type knowledge spillovers) while later attention should shift towards specialization (MAR-type of knowledge spillovers) if diversity is maintained.

Smart Specialization Strategies (S3) driven policy instruments geared towards the development of lagging regions might differ considerably to those that aim to increase efficiency and growth in already advance economies…

OK Computer: The Creation and Integration of AI in Europe

Bernardo Buarque, Ron Davies, Ryan Hynes & Dieter F. Kogler

Cambridge Journal of Regions, Economy and Society, forthcoming.

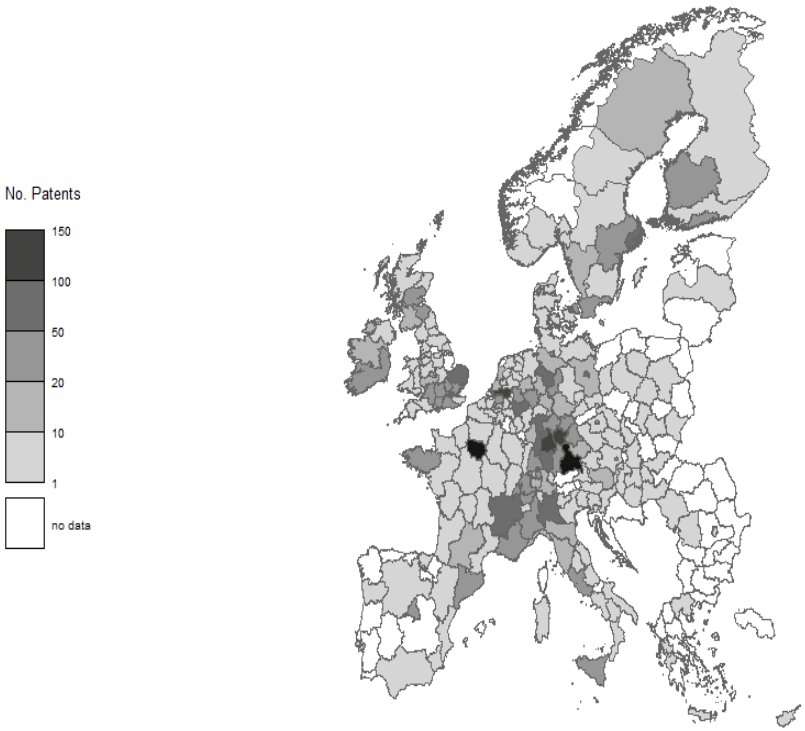
Block 1: (Y10S-706 OR G06N-003 OR G06N-005/003:G06N-005/027 OR G06N-007/005:G06N-007/06 OR G06N-099/005 OR G06T2207/20081 OR G06T2207/20084 OR G06T-003/4046 OR G06T-009/002 OR G06F-017/16 OR G05B-013/027 OR G05B-013/0275 OR G05B-013/028 OR G05B-013/0285 OR G05B-013/029 OR G05B-013/0295 OR G05B-2219/33002 OR G05D-001/0088 OR G06K-009 OR G10L-015 OR G10L-017 OR G06F-017/27:G06F-017/2795 OR G06F-017/28:G06F-017/289 OR G06F-017/30029:G06F-017/30035 OR G06F-017/30247:G06F-017/30262 OR G06F-017/30401 OR G06F-017/3043 OR G06F-017/30522:G06F-017/3053 OR G06F-017/30654 OR G06F-017/30663 OR G06F-017/30666 OR G06F-017/30669 OR G06F-017/30672 OR G06F-017/30684 OR G06F-017/30687 OR G06F-017/3069 OR G06F-017/30702 OR G06F-017/30705:G06F-017/30713 OR G06F-017/30731:G06F-017/30737 OR G06F-017/30743:G06F-017/30746 OR G06F-017/30784:G06F-017/30814 OR G06F-019/24 OR G06F-019/707 OR G01R-031/2846:G01R-031/2848 OR G01N-2201/1296 OR G01N-029/4481 OR G01N-033/0034 OR G01R-031/3651 OR G01S-007/417 OR G06N-003/004:G06N-003/008 OR G06F-011/1476 OR G06F-011/2257 OR G06F-011/2263 OR G06F-015/18 OR G06F-2207/4824 OR G06K-007/1482 OR G06N-007/046 OR G11B-020/10518 OR G10H-2250/151 OR G10H-2250/311 OR G10K-2210/3024 OR H01J-2237/30427 OR H01M-008/04992 OR H02H-001/0092 OR H02P-021/0014 OR H02P-023/0018 OR H03H-2017/0208 OR H03H-2222/04 OR H04L-2012/5686 OR H04L-2025/03464 OR H04L-2025/03554 OR H04L-025/0254 OR H04L-025/03165 OR H04L-041/16 OR H04L-045/08 OR H04N-021/4662:H04N-021/4666 OR H04Q-2213/054 OR H04Q-2213/13343 OR H04Q-2213/343 OR H04R-025/507 OR G08B-029/186 OR B60G-2600/1876 OR B60G-2600/1878 OR B60G-2600/1879 OR B64G-2001/247 OR E21B-2041/0028 OR B23K-031/006 OR B29C-2945/76979 OR B29C-066/965 OR B25J-009/161 OR A61B-005/7264:A61B-005/7267 OR Y10S-128/924 OR Y10S-128/925 OR F02D-041/1405 OR F03D-007/046 OR F05B-2270/707 OR F05B-2270/709 OR F16H-2061/0081 OR F16H-2061/0084 OR B60W-030/06

+

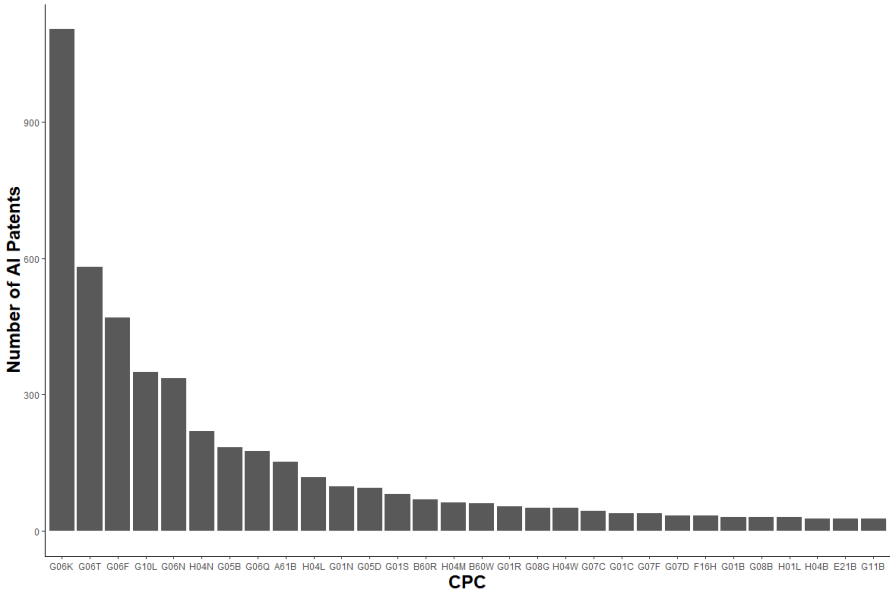
K1 = (((ARTIFIC+ OR COMPUTATION+) 1W INTELLIGEN+) OR (NEURAL 1W NETWORK+) OR NEURAL_NETWORK+ OR NEURAL_NETWORK+ OR (BAYES+ 1W NETWORK+) OR BAYESIAN-NETWORK+ OR BAYESIAN_NETWORK+ OR (CHATBOT?) OR (DATA 1W MINING+) OR (DECISION 1W MODEL?) OR (DEEP 1W LEARNING+) OR DEEP-LEARNING+ OR DEEP_LEARNING+ OR (GENETIC 1W ALGORITHM?) OR ((INDUCTIVE 1W LOGIC) 1D PROGRAMM+) OR (MACHINE 1W LEARNING+) OR MACHINE_LEARNING+ OR MACHINE-LEARNING+ OR ((NATURAL 1D LANGUAGE) 1W (GENERATION OR PROCESSING)) OR (REINFORCEMENT 1W LEARNING) OR (SUPERVISED 1W (LEARNING+ OR TRAINING)) OR SUPERVISED-LEARNING+ OR SUPERVISED_LEARNING+ OR (SWARM 1W INTELLIGEN+) OR SWARM-INTELLIGEN+ OR SWARM_INTELLIGEN+ OR (UNSUPERVISED 1W (LEARNING+ OR TRAINING)) OR UNSUPERVISED-LEARNING+ OR UNSUPERVISED_LEARNING+ OR (SEMI-SUPERVISED 1W (LEARNING+ OR TRAINING)) OR SEMI-SUPERVISED-LEARNING OR SEMI_SUPERVISED_LEARNING+OR CONNECTIONIS# OR (EXPERT 1W SYSTEM?) OR (FUZZY 1W LOGIC?) OR TRANSFER-LEARNING OR TRANSFER_LEARNING OR (TRANSFER 1W LEARNING) OR (LEARNING 3W ALGORITHM?) OR (LEARNING 1W MODEL?) OR (SUPPORT VECTOR MACHINE?) OR (RANDOM FOREST?) OR (DECISION TREE?) OR (GRADIENT TREE BOOSTING) OR (XGBOOST) OR ADABOOST OR RANKBOOST OR (LOGISTIC REGRESSION) OR (STOCHASTIC GRADIENT DESCENT) OR (MULTILAYER PERCEPTRON?) OR (LATENT SEMANTIC ANALYSIS) OR (LATENT DIRICHLET ALLOCATION) OR (MULTI-AGENT SYSTEM?) OR (HIDDEN MARKOV MODEL?))/**BI/OBJ/CLMS**

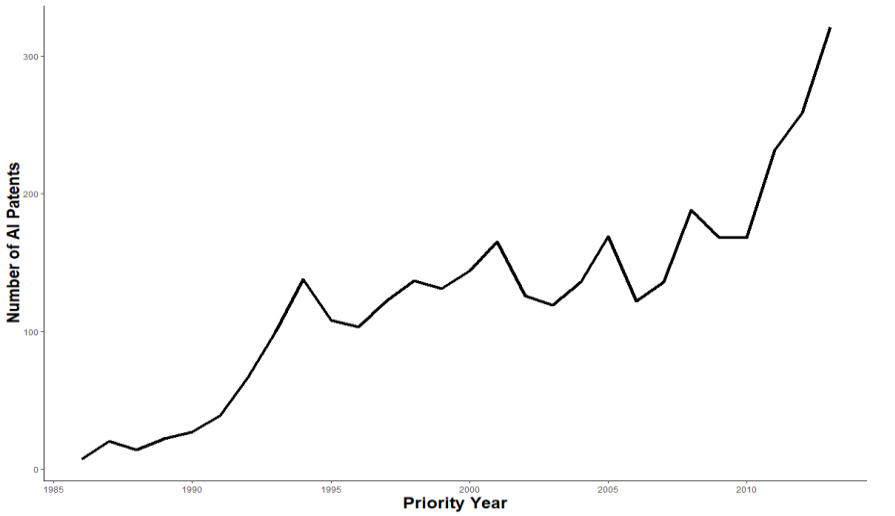
Source: (WIPO, 2019)

AI – Knowledge Domains, Location & Growth



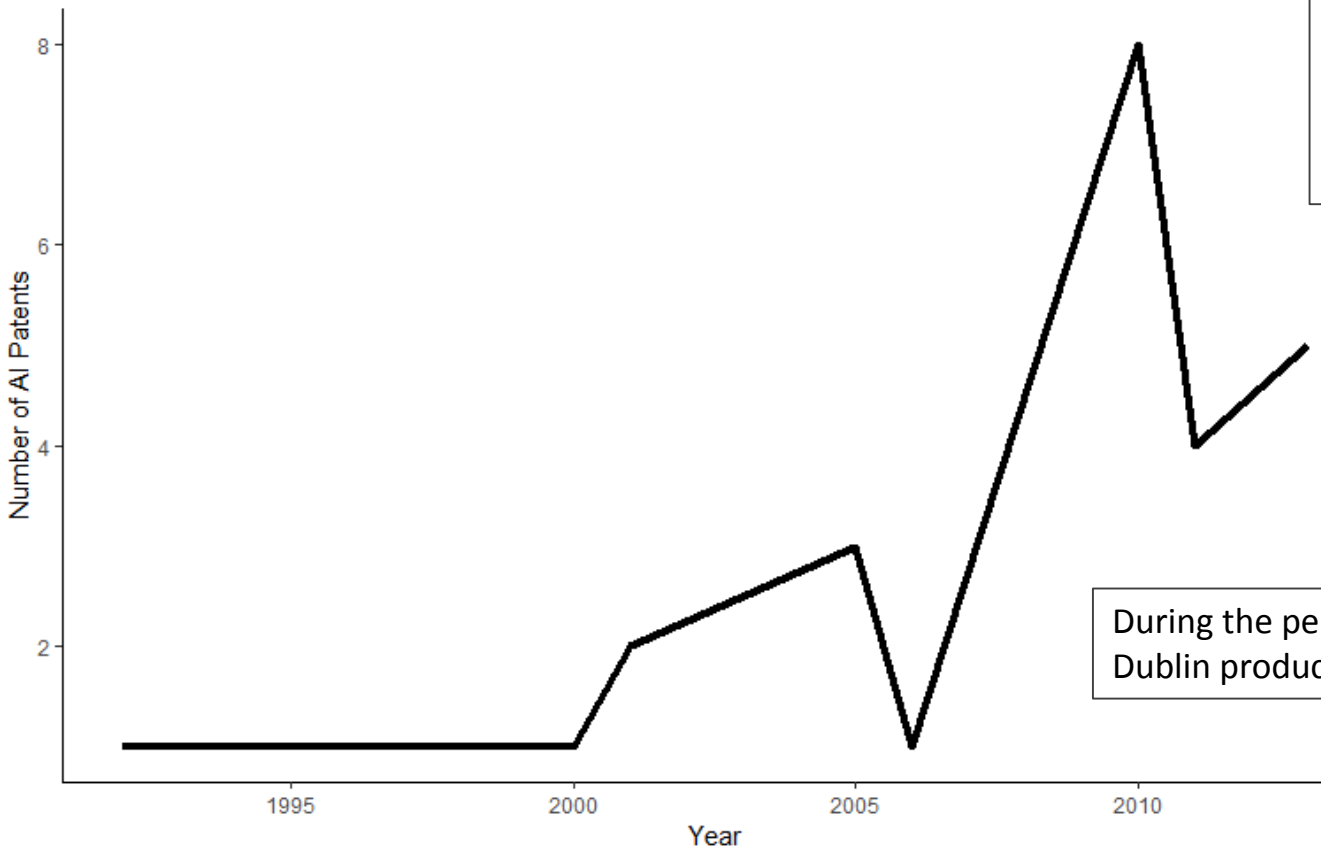
EU NUTS2 AI Patents - 2013





Artificial Intelligence in Dublin

Number of AI patent applications in Dublin (IE021) from 1980 to 2013

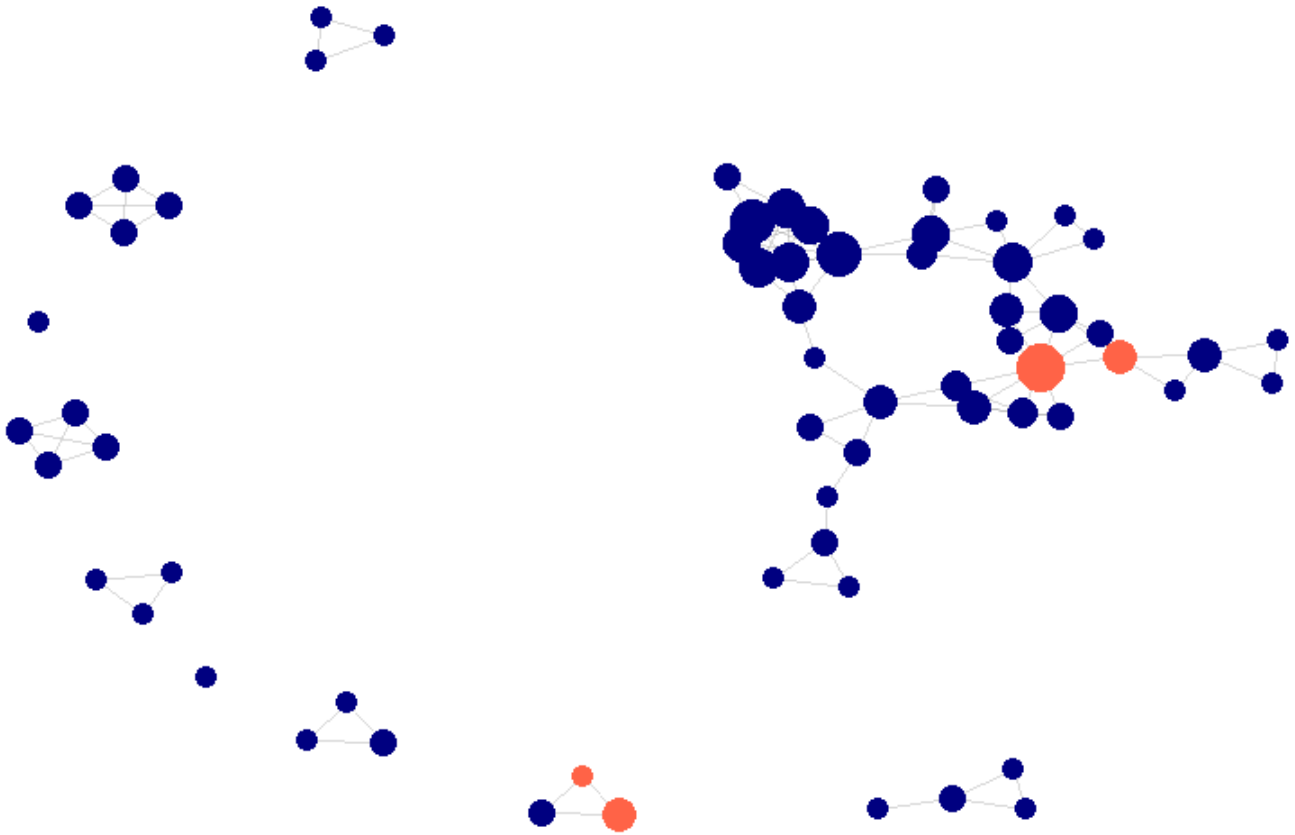


Like what we observe all around Europe, there seems to be a peak in AI patenting in Dublin from 2010 onwards.

During the period under consideration, Dublin produced a total of 28 AI patents.

The AI Centrality Index (AICI)

Dublin's Knowledge Space (IE021) between 1987-1990



In red, we highlighted the 12 AI-related CPC codes.

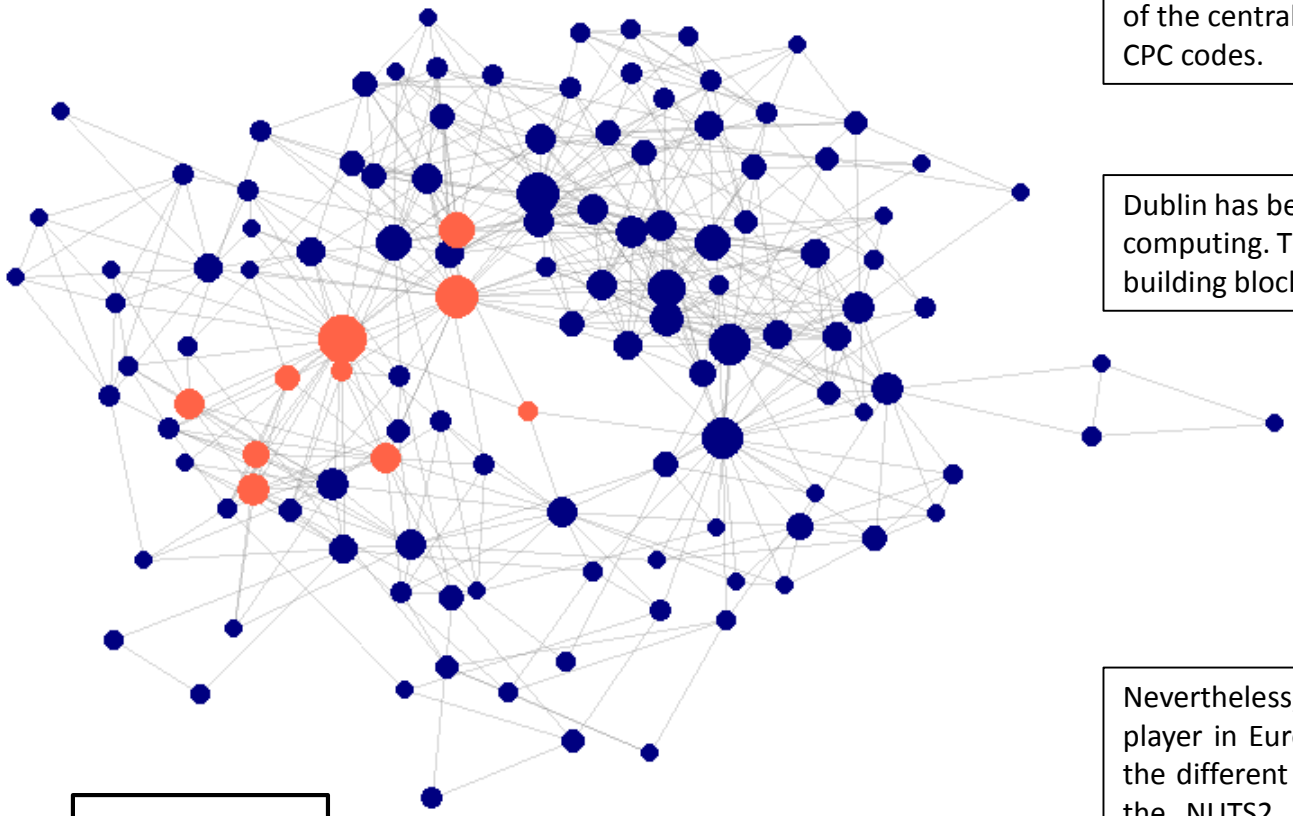
AICI measures the overall change in the network statistics when we omit the 12 AI-related CPCs.

AICI = 83

To construct the index, I used the weights from a principal component analysis applied to network statistics collected for all NUTS2 regions. Then, we calculated AICI for Dublin – NUTS3 level.

Artificial Intelligence Knowledge Space

Knowledge Space for Dublin (IE021) between 2008 and 2013



AICI = 303

There was significant growth in terms of the centrality of those 12 AI-related CPC codes.

Dublin has become specialized in computing. The city has the necessary building blocks to enter the AI market.

Nevertheless, Dublin is not yet a key AI-player in Europe. As we can infer from the different rankings used to compare the NUTS2 regions - Buarque et al. (2019).

Artificial Intelligence Knowledge Space

Top AI producers in Europe between 1980 and 2013

NUTS2	No.app	Ranking
FR10	266	1
DE21	240	2
DE25	143	3
NL41	117	4
DE11	111	5
DE12	77	6
DE71	71	7
UKH1	69	8
ITC4	64	9
DE30	63	10
DEA2	63	10
FR71	58	11
DE14	57	12
DE92	56	13
SE11	55	14
SE22	46	15
UKJ2	45	16
UKJ1	42	17
FI1B	41	18
FR82	39	19
UKK1	38	20
CH04	36	21
DE23	36	21
ES51	36	21
CH01	35	22
DE13	35	22
IE02	35	22
ITG1	35	22
ITC1	31	23
BE21	30	24
ES30	30	24
UKI3	30	24
UKI4	30	24
DEA1	29	25

Dublin is among the 25 top AI producing regions in Europe. However, regarding specialization in computing, it has only the 40th largest share of patents on the 12 AI-related CPC codes.

Largest shares of AI related CPC codes between 1980 and 2013

NUTS2	Share	Ranking
FR10	0.069262	1
DE21	0.056401	2
NL41	0.054477	3
SE11	0.029469	4
DE11	0.027379	5
DE12	0.025659	6
FI1B	0.02525	7
DE25	0.022528	8
FR52	0.019929	9
FR71	0.019321	10
FR82	0.018248	11
DE71	0.018062	12
DE13	0.017222	13
DEA2	0.017203	14
UKH1	0.014547	15
DE30	0.014471	16
SE22	0.014162	17
UKJ1	0.014062	18
UKJ2	0.01325	19
UKK1	0.012993	20
UKJ3	0.012884	21
FI19	0.012761	22
CH04	0.011492	23
ITC4	0.010656	24
DE92	0.010604	25
DE14	0.010157	26
CH02	0.010015	27
UKI3	0.00972	28
BE21	0.00914	29
DEA1	0.008998	30
CH01	0.008846	31
SE12	0.008803	32
DE27	0.007402	33
DEB3	0.007112	34
CH03	0.007074	35
NL33	0.006884	36
DK01	0.006722	37
FI1D	0.006414	38
UKH2	0.0063	39
IE02	0.006176	40

Artificial Intelligence Knowledge Space

Largest AICI in Europe between 1980 and 2013

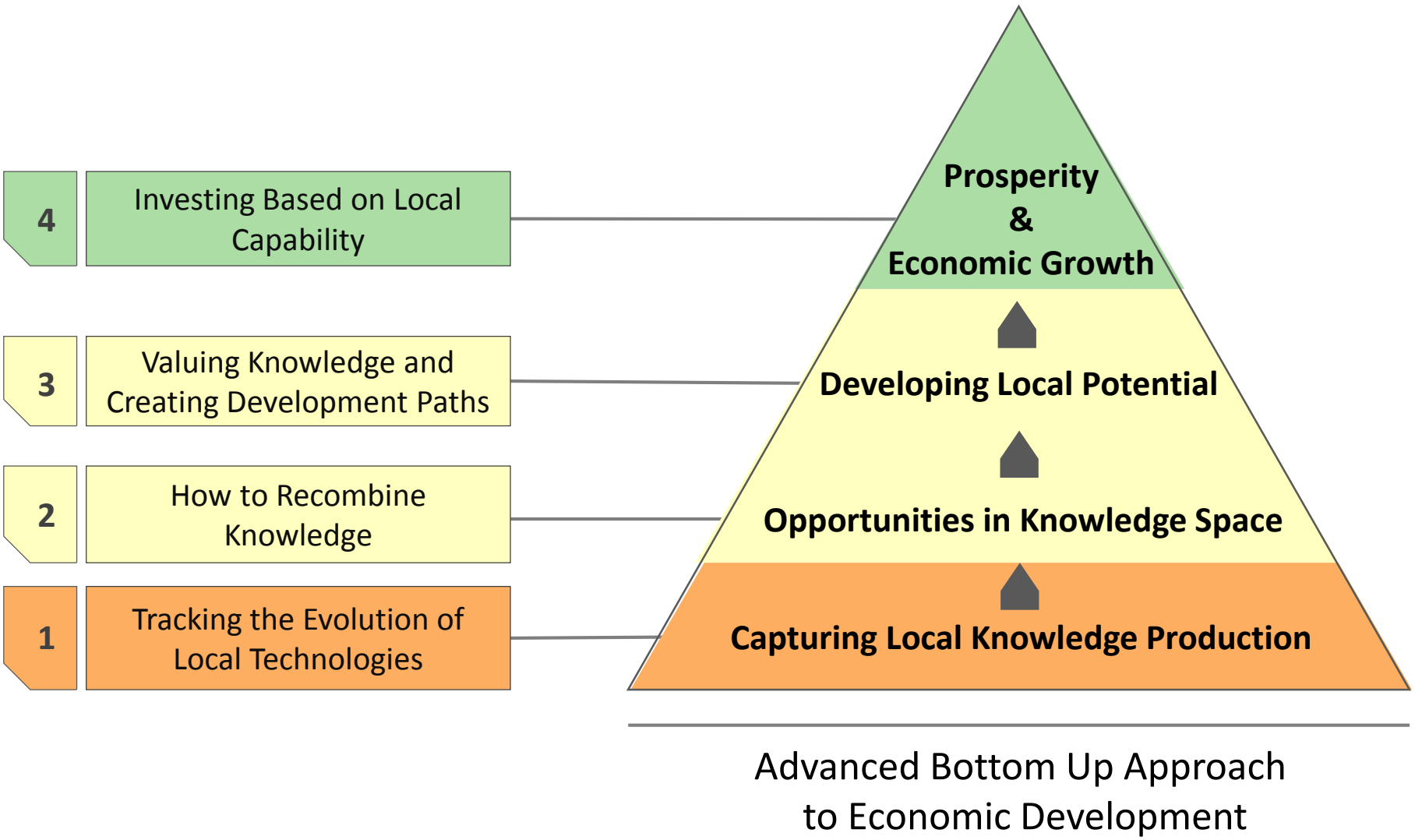
NUTS	AICI	Ranking
ITC1	6.350925	1
SE32	4.86176	2
DE21	4.852207	3
FR23	3.447266	4
SE33	2.80096	5
DE71	2.41966	6
UKH1	2.405457	7
FR10	2.358888	8
DK04	2.323565	9
FRZZ	2.166463	10
UKG3	1.943586	11
UKK1	1.789818	12
DE27	1.784927	13
IE01	1.766425	14
UKM3	1.738448	15
CZ06	1.670304	16
PT17	1.643199	17
ITI4	1.63923	18
ES61	1.615257	19
SI04	1.564548	20
NO01	1.5186	21
NL41	1.481202	22
DE91	1.464005	23
UKI3	1.445759	24
UKJ3	1.41697	25
.	.	.
.	.	.
.	.	.
IE02	0.353240521	100

When we omit all the AI patents from the Dublin knowledge space, it does not produce particularly significant effects. The region is only number 100th in the European ranking. Thus, computing expertise has not yet translated into AI specialization.

Omitting the 12 AI-related CPCs produces a relatively larger impact on Dublin's knowledge space. When we use this methodology, the region becomes the 52nd in the European ranking of AI centrality.

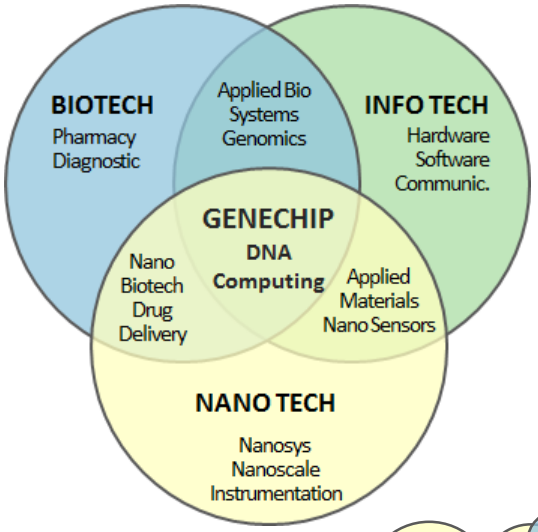
NUTS	AICI	Ranking
FR10	297.4417	1
DE21	277.7954	2
DE11	194.6419	3
NL41	181.7336	4
DE12	170.2006	5
DE71	166.3244	6
FR71	161.1041	7
DEA2	151.4684	8
DE13	138.4664	9
DE25	137.8873	10
DE30	129.8216	11
DEA1	125.5095	12
CH04	123.7318	13
UKH1	121.2482	14
UKJ1	118.0884	15
SE11	116.7638	16
DE14	116.5758	17
FI1B	114.3895	18
UKJ2	112.932	19
ITC4	110.5305	20
CH01	108.311	21
FR82	102.7323	22
SE22	101.3993	23
CH02	101.3785	24
SE12	98.13865	25
DEA5	96.88259	26
DE92	96.06157	27
DE27	95.04496	28
CH03	94.29716	29
DK01	93.84392	30
UKK1	92.35222	31
UKI3	86.19898	32
UKJ3	85.81611	33
DEB3	85.81226	34
.	.	.
.	.	.
.	.	.
IE02	65.97607	52

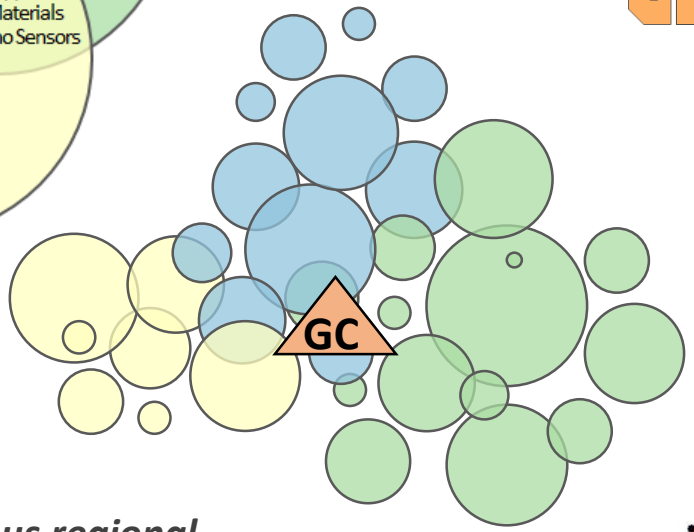
"Really" Smart Specialisation Strategies

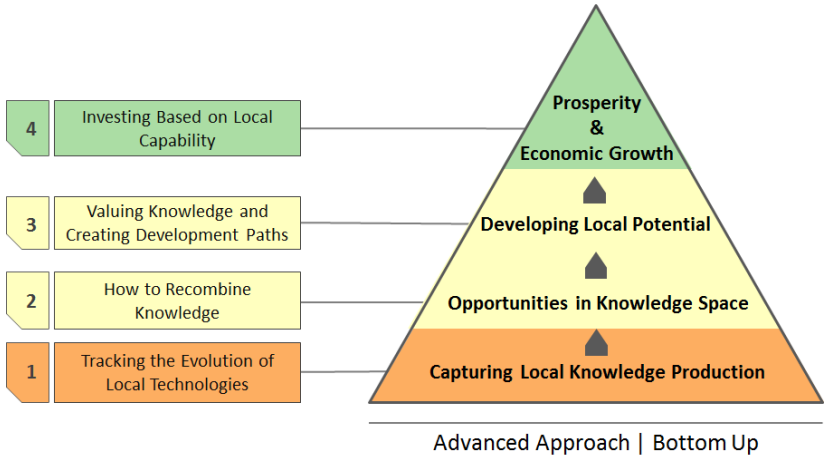


Technology Evolution in Regional Economies [TechEvo]

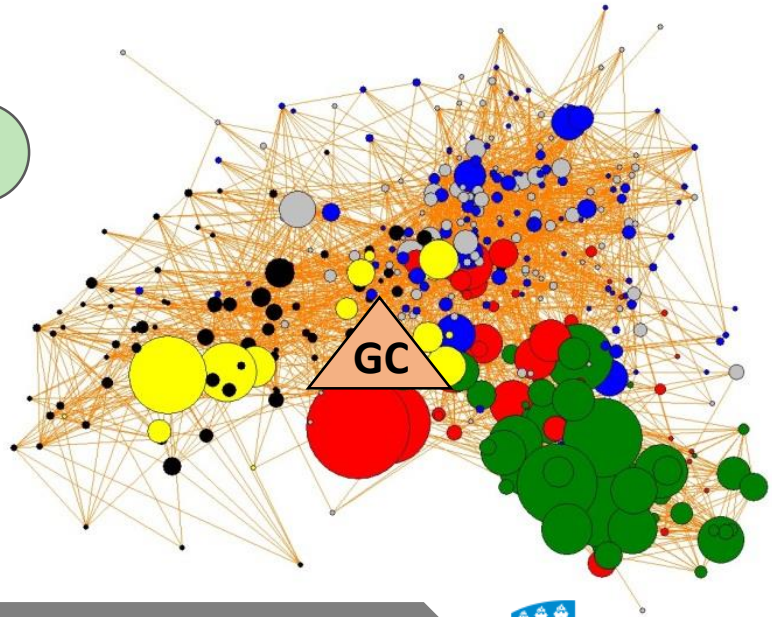
Economic Reality







Knowledge Space



…from serendipitous regional evolutionary trajectories

to planned and organized development pathways…

University College Dublin
Ireland's Global University

SPATIAL DYNAMICS LAB ©

The Evolutionary Process of Knowledge Recombination & Smart Specialisation Strategies for Economic Development

Comments are Welcome – Thank you!

Technology Evolution in Regional Economies
ERC StG #715631 – TechEvo

Dieter F. Kogler

dieter.kogler@ucd.ie

@dfkogler

www.ucd.ie/sdl

UCD DUBLIN

Economic & Social Research Institute (ESRI), Dublin, Ireland, November 7th, 2019.

SPATIAL DYNAMICS LAB ©

THE EVOLUTIONARY PROCESS OF KNOWLEDGE RECOMBINATION & SMART SPECIALISATION STRATEGIES FOR ECONOMIC DEVELOPMENT

APPENDIX

Technology Evolution in Regional Economies
ERC StG #715631 – TechEvo

DIETER F. KOGLER

dieter.kogler@ucd.ie

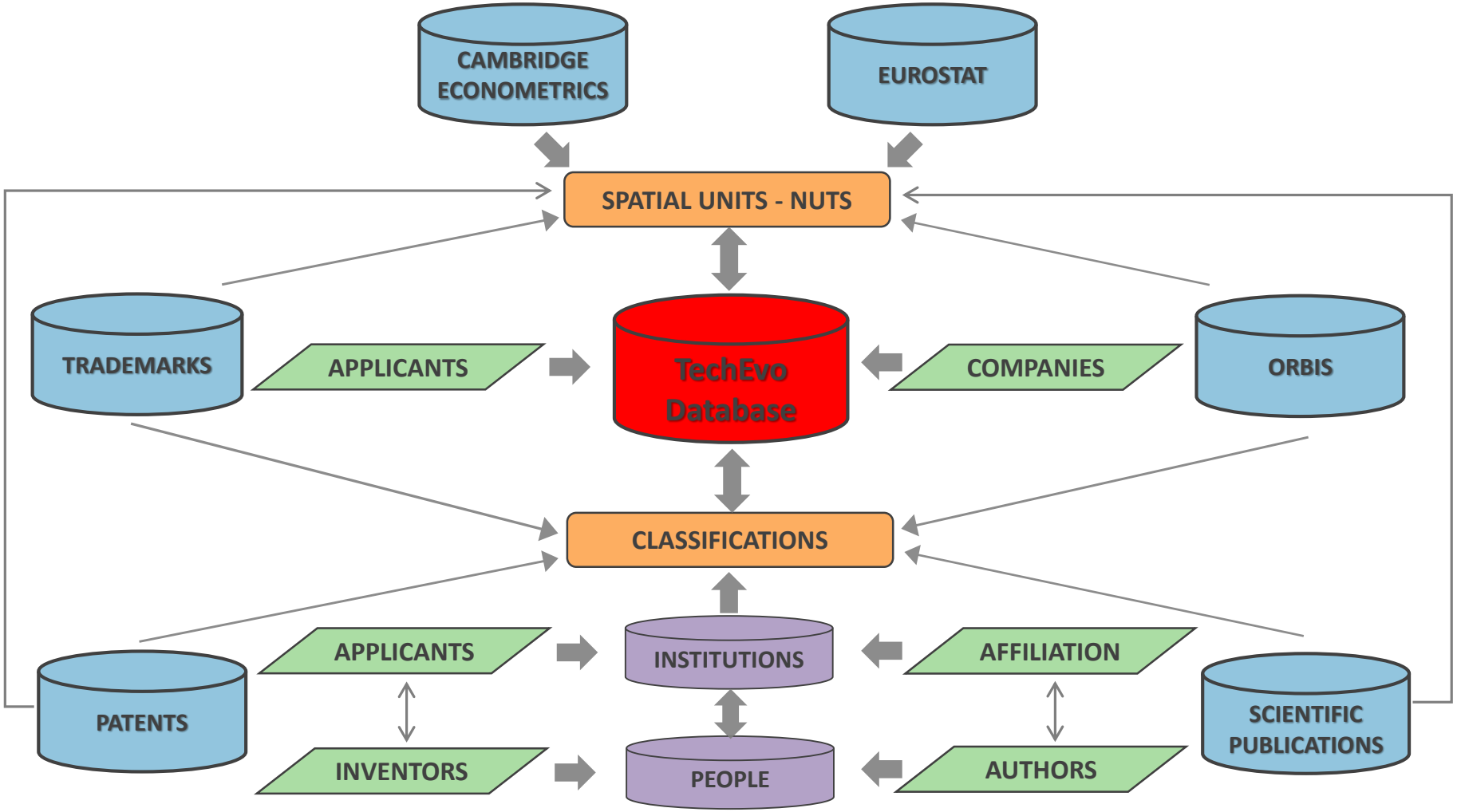
@dfkogler

www.ucd.ie/sdl

UCD DUBLIN

Economic & Social Research Institute (ESRI), Dublin, Ireland, November 7th, 2019.

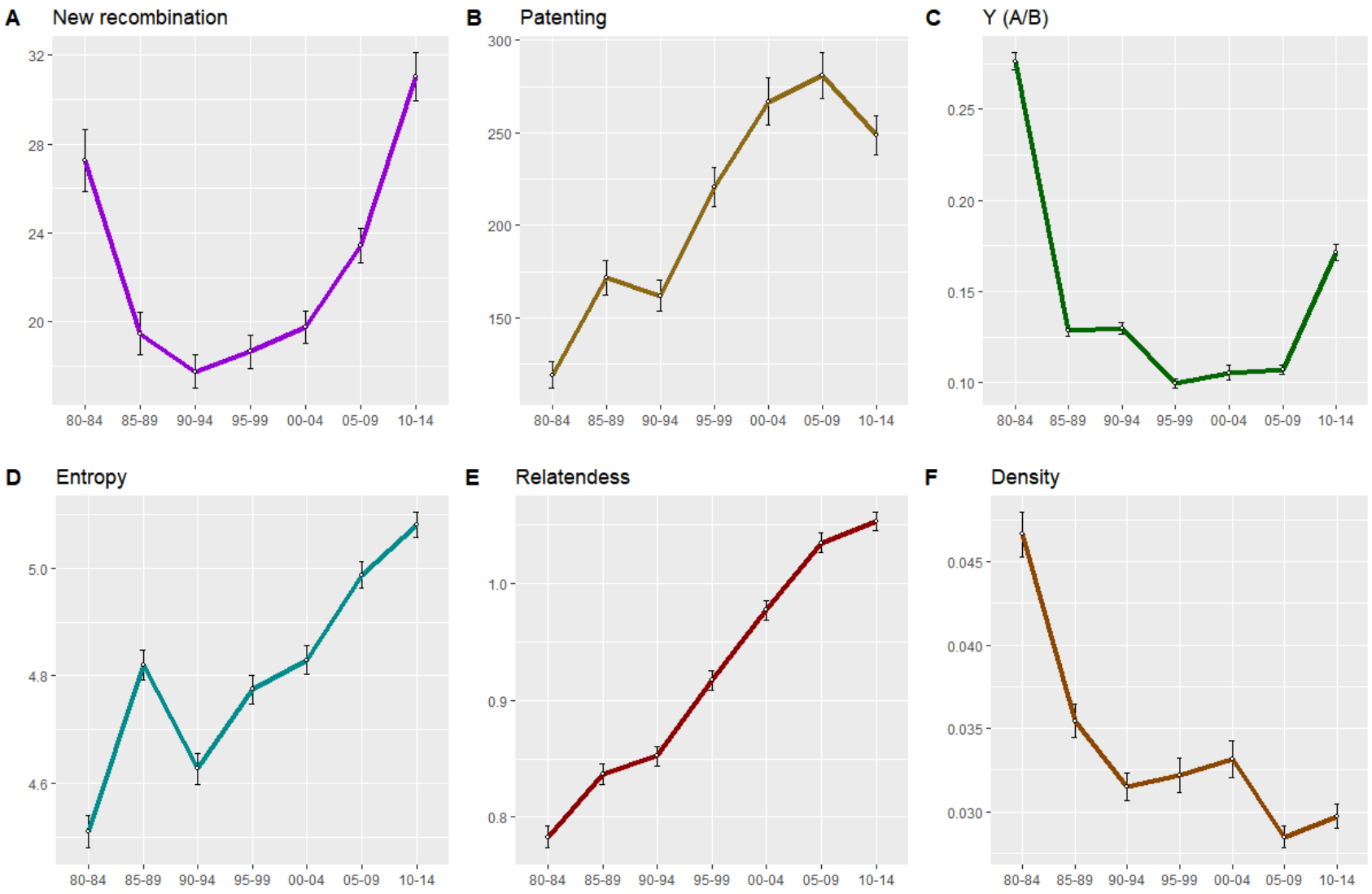
TechEvo Data Architecture



Descriptive statistics

	Metro-city Sample (N=6,137)				*Non-metro NUTS3 Sample (N=13,544)*			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
New Recomb. by Local share of PAT	0.119	0.086	0.000	0.803	0.139	0.129	0.000	1.935
Std. Entropy	0.382	0.257	-0.744	0.887	0.155	0.253	-0.869	0.728
Std. Average Relatedness	0.409	0.420	-0.630	1.331	0.029	0.344	-0.776	2.475
Std. Network Density	-0.141	0.259	-0.583	1.730	-0.028	0.295	-0.958	1.265
GDP per capita (1B euro in 2005)	0.024	0.009	0.003	0.079	0.022	0.007	0.004	0.065
Employment rate (Employ / POP)	0.448	0.067	0.248	0.692	0.435	0.089	0.133	0.993
Patenting per capita (Local share of PAT / POP)	0.652	0.961	0.006	12.417	0.495	0.551	0.012	6.333

Trend of variables



RESULTS (Metro-city regions)

	Model 1			*Model 2*			*Model 3*		
Var.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Entropy	0.136	***	0.009						
Relatedness	0.006		0.005						
ETP×REL	0.024	*	0.011						
Entropy				0.188	***	0.010			
Density				0.040	***	0.007			
ETP×DST				0.041	***	0.011			
Relatedness							0.035	***	0.005
Density							-0.021	***	0.006
REL×DST							0.018	*	0.009
GDPpct	1.061	**	0.336	0.897	**	0.334	0.367		0.344
EmpRate	-0.066	*	0.032	-0.041		0.032	-0.014		0.033
PATpct	0.007	**	0.002	0.003		0.002	0.000		0.002
Constant	0.142	***	0.021	0.141	***	0.021	0.236	***	0.020
Period FE	Y			Y			Y		
REG FE	Y			Y			Y		
Country RE	Y			Y			Y		
no. Regions-year	6,139			6,139			6,139		
no. Regions	237			237			237		
no. Countries	28			28			28		

*** p<0.001, ** p<0.01, * p<0.05

RESULTS (Non metro NUTS III regions)

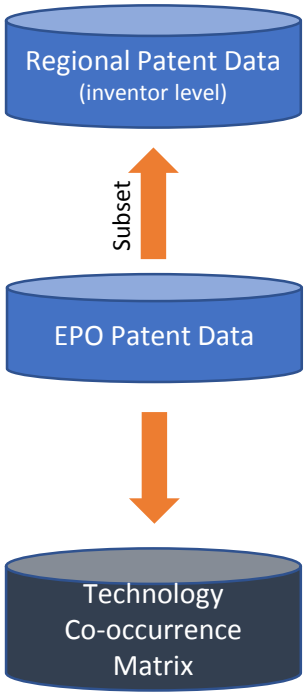
	Model 1			*Model 2*			*Model 3*		
Var.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Entropy	0.169	***	0.009						
Relatedness	0.032	***	0.007						
ETP×REL	-0.026		0.016						
Entropy				0.228	***	0.010			
Density				0.047	***	0.008			
ETP×DST				0.090	***	0.021			
Relatedness							0.060	***	0.006
Density							0.008		0.007
REL×DST							0.014		0.016
GDPpct	3.049	***	0.378	2.701	***	0.377	1.920	***	0.385
EmpRate	-0.167	***	0.032	-0.165	***	0.032	-0.107	**	0.033
PATpct	-0.007	**	0.003	-0.008	**	0.003	-0.016	***	0.003
Constant	0.195	***	0.022	0.180	***	0.021	0.255	***	0.022
Period FE	Y			Y			Y		
REG FE	Y			Y			Y		
Country RE	Y			Y			Y		
no. Regions-year	13,544			13,544			13,544		
no. Regions	571			571			571		
no. Countries	23			23			23		

*** p<0.001, ** p<0.01, * p<0.05

Regional Average Technological Relatedness

Average Relatedness of NUTS II regions by periods

(Kogler et al. 2013)



Regional weight

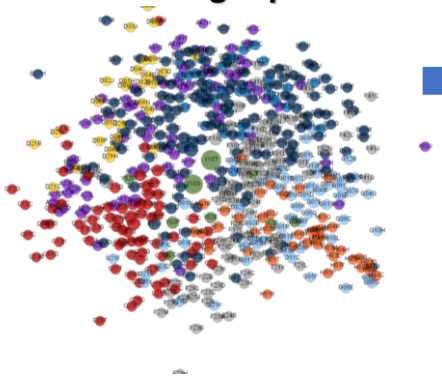
$$X_{ijr}^{t} = \frac{(P_{ir}^{t} + P_{jr}^{t})(P_{ir}^{t} + P_{jr}^{t} - 1)}{\sum_i P_{ir}^{t}(P_{ir}^{t} - 1)}$$

- X_{ijr}^{t} , Share of all possible patent-to patent links within region *r* at time *t* that link technology classes *i* and *j*
- P_{ir}^{t}: No. patents in class *i* within region *r* at time *t*

Regional Average Technology Relatedness

$$AR_r^t = \sum_i \sum_j X_{ijr}^{t} S_{ij}^{t}$$

Knowledge Space



Technology Relatedness

$$S_{ij}^{t} = \frac{N_{ij}}{\sqrt{N_i N_j}}$$

- S_{ij}^{t}: Relatedness (Proximity) btw *i* and *j* (UK level) at *t*
- N_{ij}: No. patents listing both *i* and *j*
- N_i : No. patents listing *i*
- N_j : No. patents listing *j*

Regional Technology Entropy

Method (Measurement)

(Frenken et al. 2007)

$$Entropy = \underbrace{\sum_{g=1}^{G} P_g log_2\left(\frac{1}{P_g}\right)}_{\text{Unrelated Variety}} + \underbrace{\sum_{g=1}^{G} P_g H_g}_{\text{Related Variety}}$$

,where

- p_i is 3 digit share
- P_g is 1 digit share $P_g = \sum_{i \in S_g} p_i$
- $H_g = \sum_{i \in S_g} \frac{p_i}{P_g} log_2\left(\frac{1}{p_i / P_g}\right)$

Region #1 - Patents by CPC class

1 Digit	3 Digit	No. Patent	P_g	p_i
Chemistry and Metallurgy	C07 ORGANIC CHEMISTRY	6	14/55	6/55
	C12 BIOCHEMISTRY	8		8/55
Physics	G02 OPTICS	7	9/55	7/55
	G04 HOROLOGY	2		2/55
Consumer goods	A43 FOOTWEAR	5	15/55	5/55
	A45 EQUIPMENT	4		4/55
	A47 FURNITURE	6		6/55
Mechanical Engineering	F01 ENGINES IN GENERAL	3	13/55	3/55
	F21 LIGHTING	4		4/55
	F41 WEAPONS	6		6/55
Textiles, Paper	D04 KNITTING	1	1/55	1/55
Transport	B23 MACHINE TOOLS	3	3/55	3/55
Total		55	1	1

Region #1 Entropy (3.43) = UV (2.27) + RV (1.16)

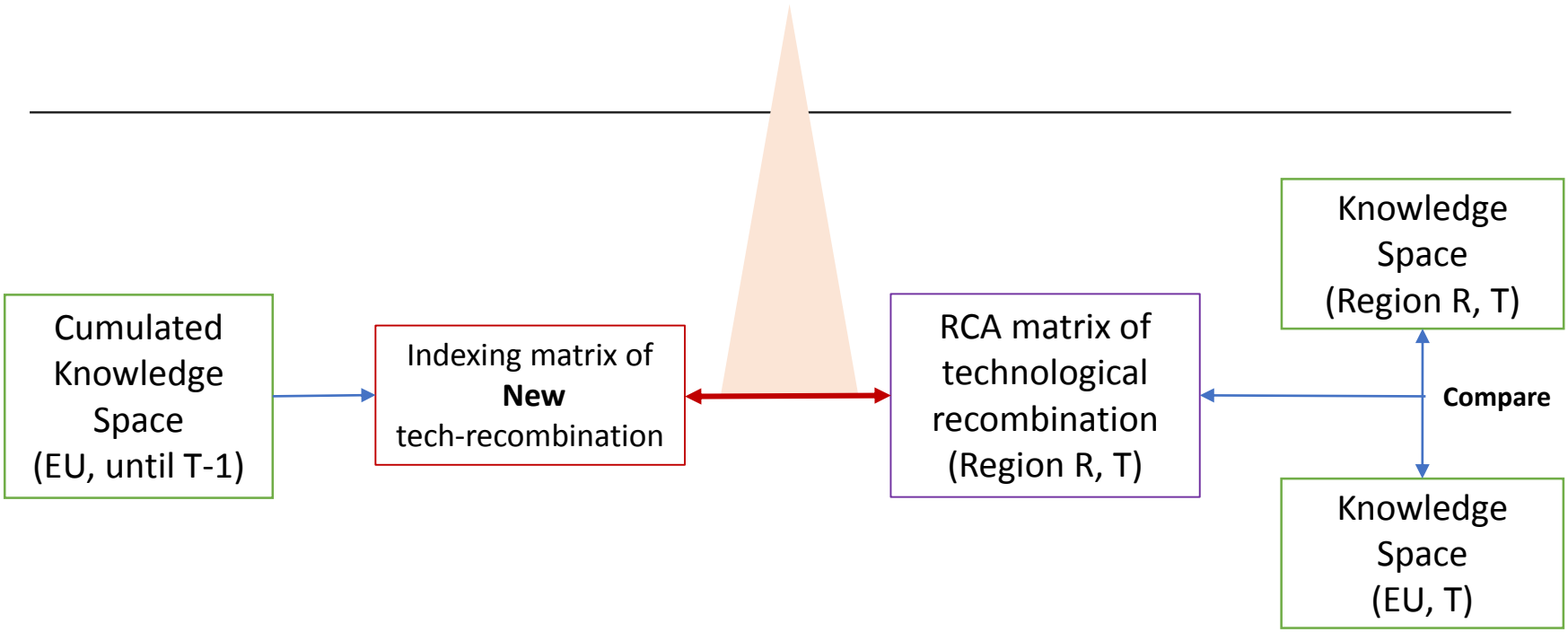
Region #2 – Patents by CPC class

1 Digit	3 Digit	No. Patent	P_g	p_i
Electrocity	H01 BASIC ELECTRIC ELEMENTS	4		4/55
	H02 CONVERSION POWER	9		9/55
	H03 ELECTRONIC CIRCUITRY	15	33/55	15/55
	H04 COMMUNICATION	3		3/55
	H05 ELECTRIC TECHNIQUES	2		2/55
Physics	G01 MEASURING / TESTING	3		3/55
	G02 OPTICS	2		2/55
	G03 PHOTOGRAPHY	3		3/55
	G05 CONTROLLING	7	22/55	7/55
	G06 COMPUTING	2		2/55
	G07 CHECKING-DEVICES	2		2/55
	G09 DISPLAY	3		3/55
Total		55	1	1

Region #2 Entropy (3.20) = UV (0.97) + RV (2.23)

A Typology of Regional Tech Recombination Activities

$$\textbf{New Recombination} = \frac{\text{Sum of each region's } \textbf{RCA} \text{ in new recombination}}{\text{Regional sum of inventor share of patents}}$$



Regional RCA in Recombination – An Example

$$RR(RCA\ in\ Recombination)_{ij} = \frac{{}^{s_{i,j,R}}/_{\sum_i \sum_j s_{i,j,R}}}{{}^{s_{i,j,EU}}/_{\sum_i \sum_j s_{i,j,EU}}}$$

Cumulated Knowledge Space (EU, until T-1)

	A	B	C	D	E
A		4	1	0	1
B			3	1	0
C				0	0
D					8
E					

New recombination space

	A	B	C	D	E
A		0	0	1	0
B			0	0	1
C				1	1
D					0
E					

RCA (Absolute RCA > 1) matrix of technological recombination (region *R*, *T*)

	A	B	C	D	E
A		3.3	0.6	0.3	1.1
B			2.2	0.4	0.9
C				1	0.7
D					0.1
E					

Knowledge Space (Region *R*, *T*)

	A	B	C	D	E
A					
B					
C					
D					
E					

Compare

Knowledge Space (*EU*, *T*)

	A	B	C	D	E
A					
B					
C					
D					
E					

Sum of **new combinations** in region's (*R*) recombinant RCA matrix = 2.9

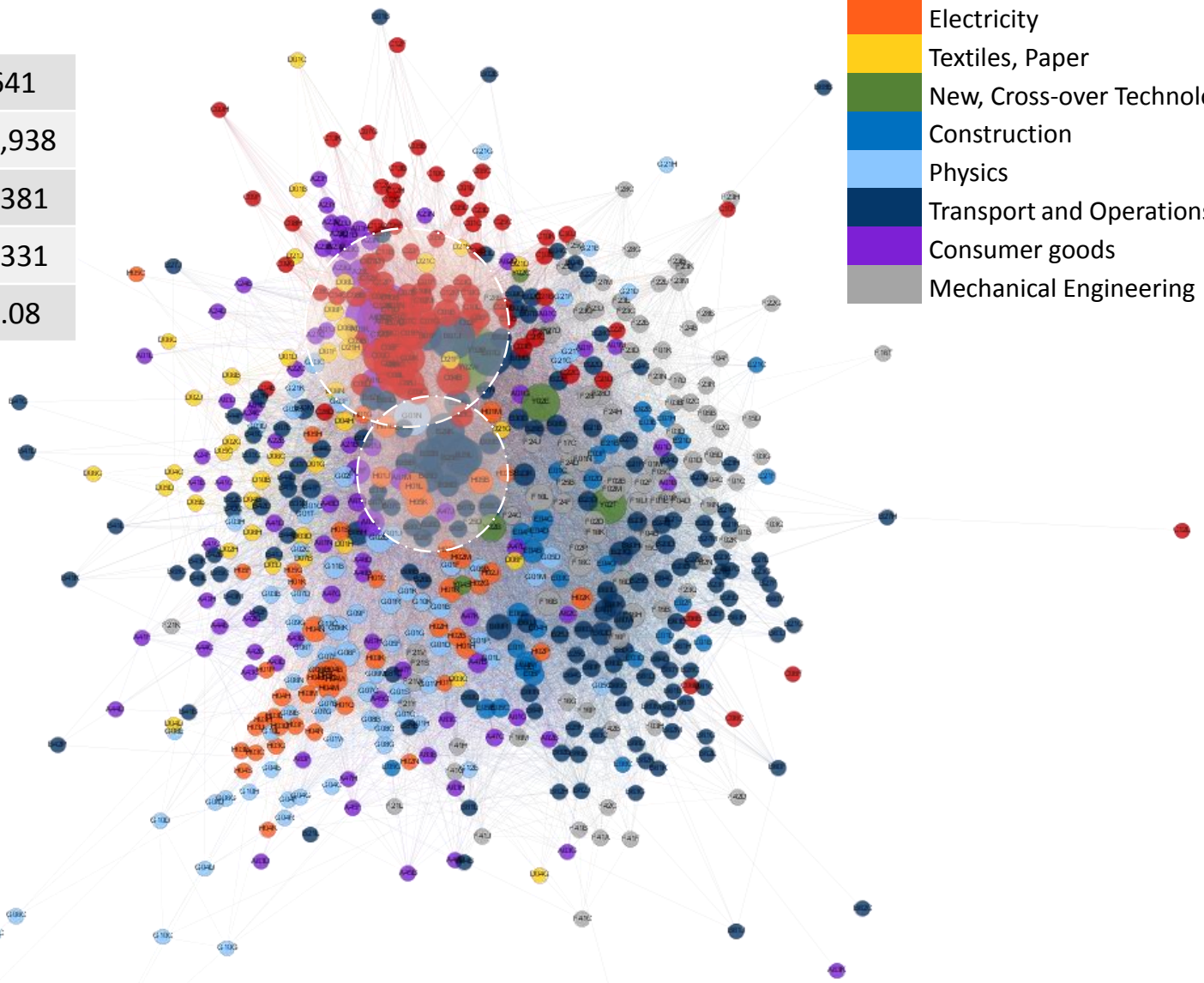
Top 5. Recombination in EU

Period	Top 5 Recombination A-B				Weight
80-84	Preservation of bio-organisms	A01N	C07D	Heterocyclic compounds	782.8
	Acyclic or carbocyclic compounds	C07C	C07D	Heterocyclic compounds	760.6
	Shaping or joining plastics	B29C	B29L	Basic articles	455.4
	Shaping or joining plastics	B29C	B29K	Moulding materials	453.0
	Preparation for medical purpose	A61K	C07K	Peptides	379.9
85-89	Preparation for medical purpose	A61K	C07K	Peptides	992.8
	Preparation for medical purpose	A61K	A61Q	Specific use of cosmetics or toilet preparations	939.0
	Preservation of bio-organisms	A01N	C07D	Heterocyclic compounds	883.1
	Acyclic or carbocyclic compounds	C07C	C07D	Heterocyclic compounds	749.0
	Shaping or joining plastics	B29C	B29K	Moulding materials	748.7
90-94	Preparation for medical purpose	A61K	A61Q	Specific use of cosmetics or toilet preparations	2,030.0
	Preparation for medical purpose	A61K	C07K	Peptides	1,830.0
	Acyclic or carbocyclic compounds	C07C	C07D	Heterocyclic compounds	1,273.0
	Peptides	C07K	C12N	Microorganisms or enzymes	1,140.0
	Preservation of bio-organisms	A01N	C07D	Heterocyclic compounds	1,015.0
95-99	Preparation for medical purpose	A61K	A61Q	Specific use of cosmetics or toilet preparations	4,093.3
	Preparation for medical purpose	A61K	C07K	Peptides	3,408.6
	Preparation for medical purpose	A61K	C12N	Microorganisms or enzymes	2,028.9
	Peptides	C07K	C12N	Microorganisms or enzymes	1,982.9
	Acyclic or carbocyclic compounds	C07C	C07D	Heterocyclic compounds	1,555.5
00-04	Preparation for medical purpose	A61K	A61Q	Specific use of cosmetics or toilet preparations	5,953.3
	Preparation for medical purpose	A61K	C07K	Peptides	4,491.0
	Transmission of digital information	H04L	H04W	Wireless communications networks	3,414.8
	Preparation for medical purpose	A61K	C12N	Microorganisms or enzymes	2,684.8
	Peptides	C07K	C12N	Microorganisms or enzymes	2,436.6
05-09	Preparation for medical purpose	A61K	A61Q	Specific use of cosmetics or toilet preparations	5,956.8
	Transmission of digital information	H04L	H04W	Wireless communications networks	4,673.6
	Preparation for medical purpose	A61K	C07K	Peptides	3,976.9
	Shaping or joining plastics	B29C	B29L	Basic articles	3,282.9
	Shaping or joining plastics	B29C	B29K	Moulding materials	3,040.6
10-14	Transmission of digital information	H04L	H04W	Wireless communications networks	5,144.0
	Preparation for medical purpose	A61K	A61Q	Specific use of cosmetics or toilet preparations	4,716.7
	Shaping or joining plastics	B29C	B29L	Basic articles	3,524.6
	Preparation for medical purpose	A61K	C07K	Peptides	3,436.0
	Shaping or joining plastics	B29C	B29K	Moulding materials	2,948.8

EU Knowledge Space Evolution and Recombination Hotspots

(1990-1994)

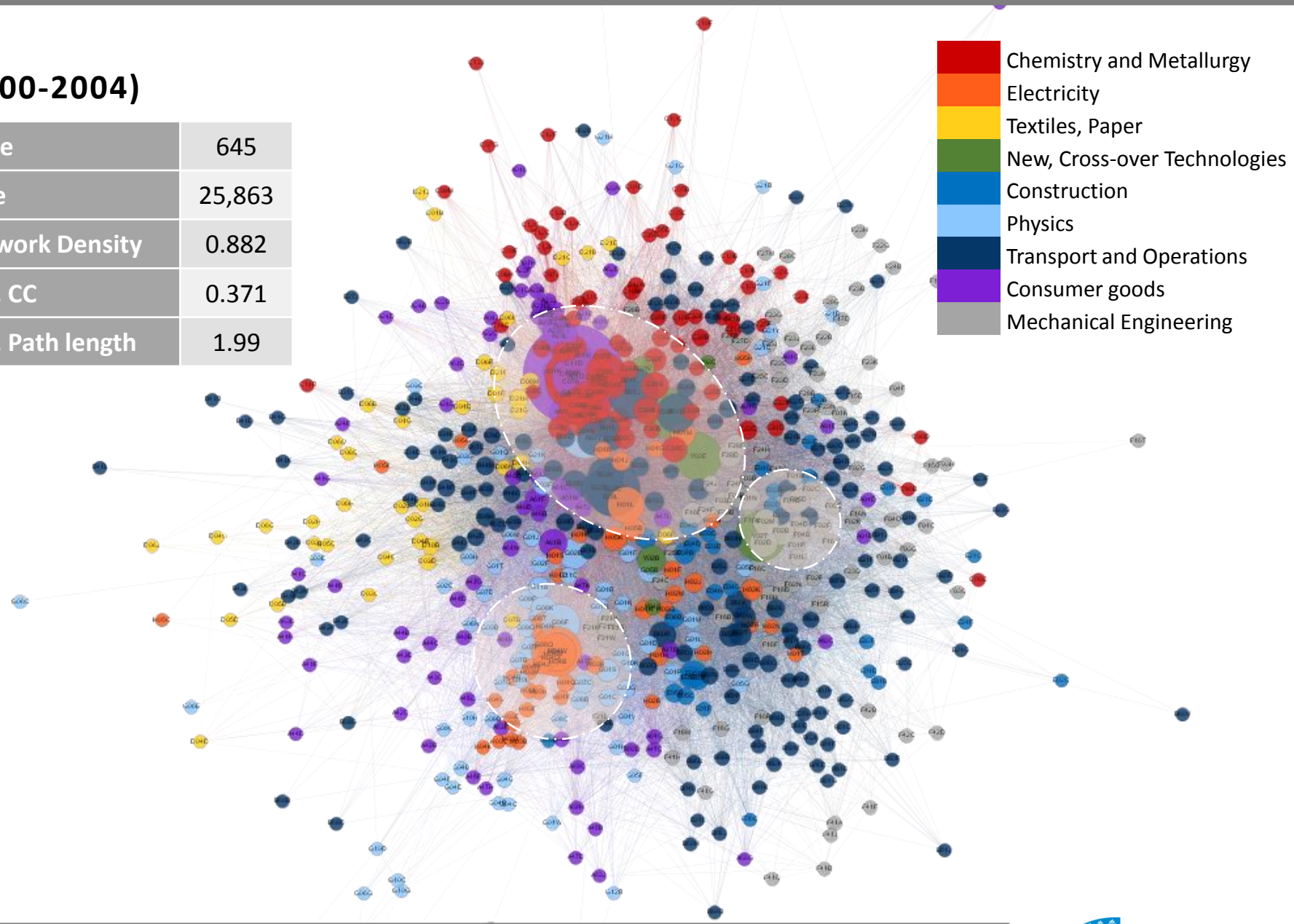
Node	641
Edge	19,938
Network Density	0.381
Ave. CC	0.331
Ave. Path length	2.08



EU Knowledge Space Evolution and Recombination Hotspots

(2000-2004)

Node	645
Edge	25,863
Network Density	0.882
Ave. CC	0.371
Ave. Path length	1.99



EU Knowledge Space – Network Measures

period	no.node	no.edge	density	diameter	avg.path	avg.cc
80-84	633	13,947	0.166	9.00	2.21	0.282
85-89	639	17,454	0.260	6.58	2.12	0.309
90-94	641	19,938	0.381	9.00	2.08	0.331
95-99	645	22,673	0.586	7.50	2.04	0.346
00-04	645	25,863	0.882	5.33	1.99	0.371
05-09	649	30,450	1.247	6.25	1.94	0.399
10-14	645	35,967	1.512	5.41	1.89	0.44