The Economy as a Complex System

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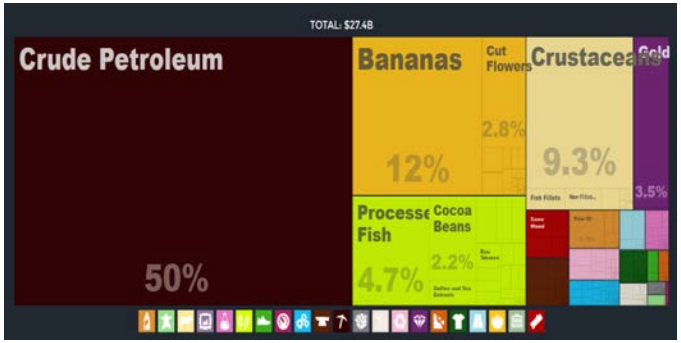
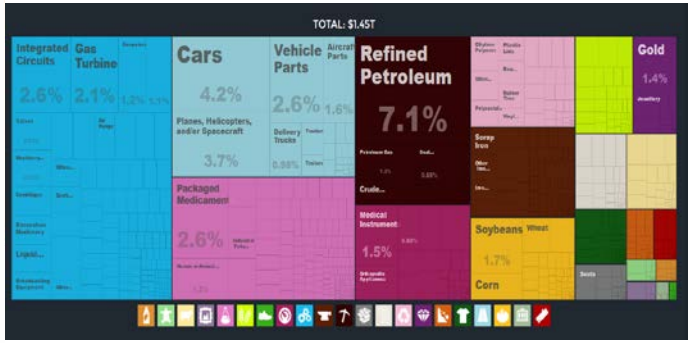
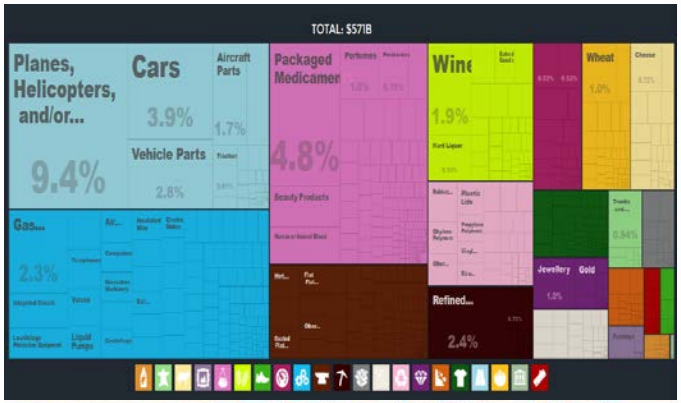
Reframing economic development

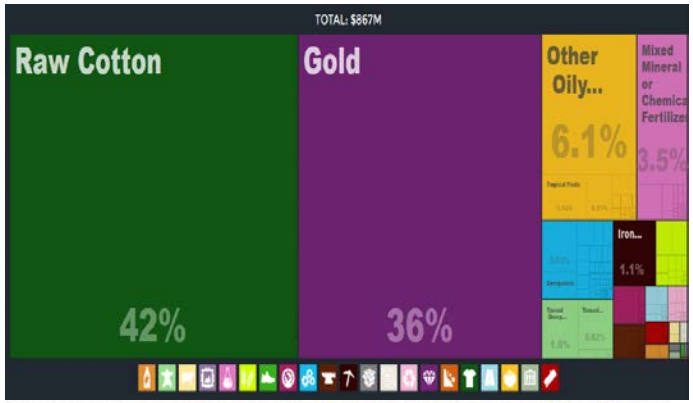
Data Source: PovcalNet - World Bank

Reframing economic development



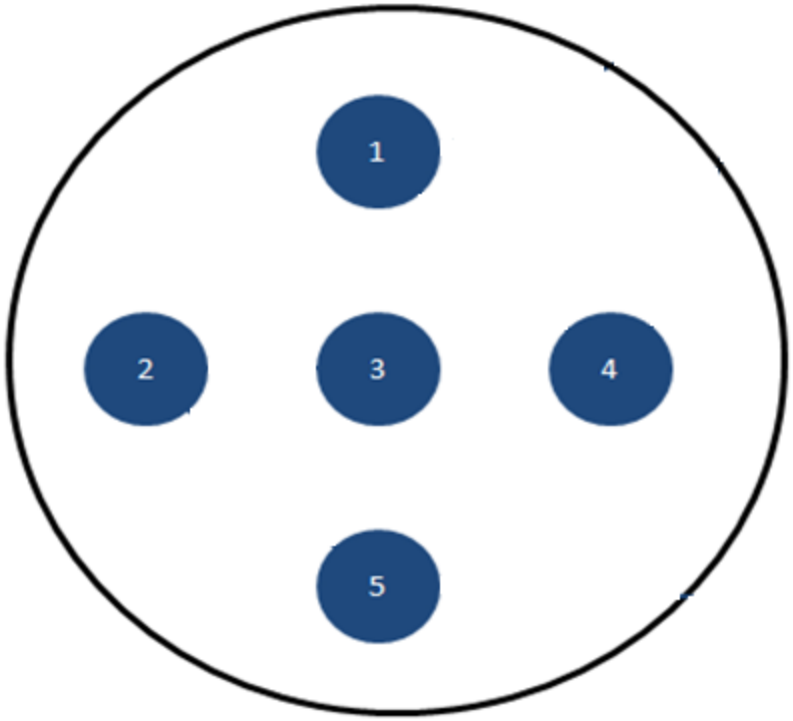




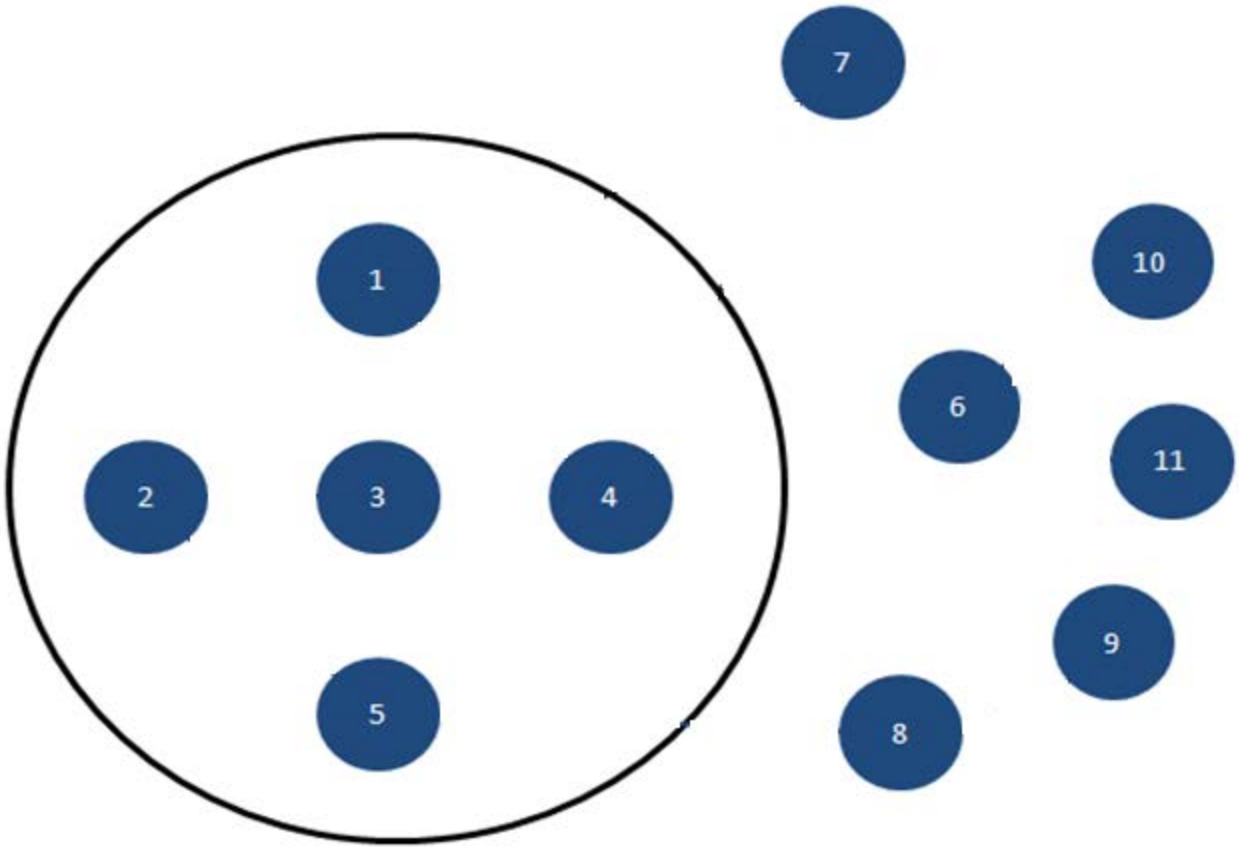


Data Source: atlas.media.mit.edu

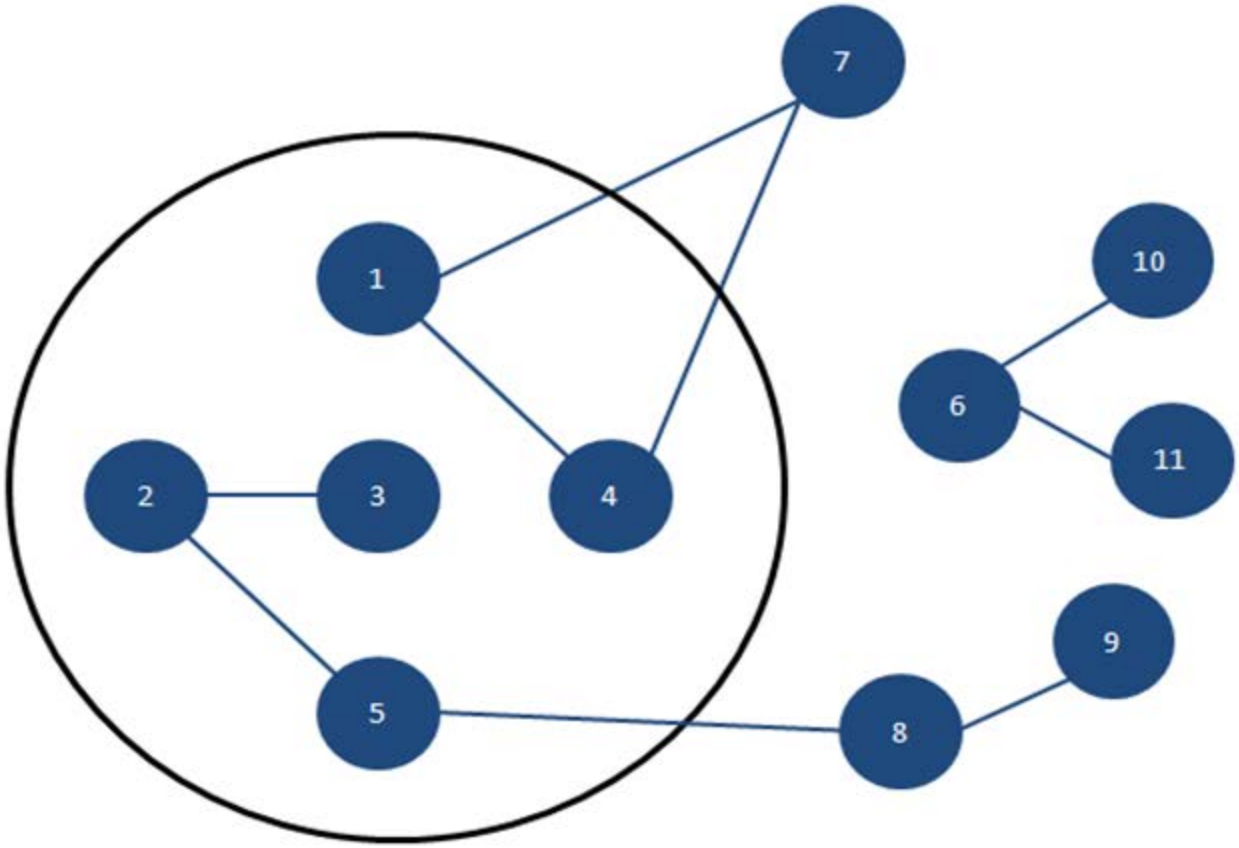
Economic structures



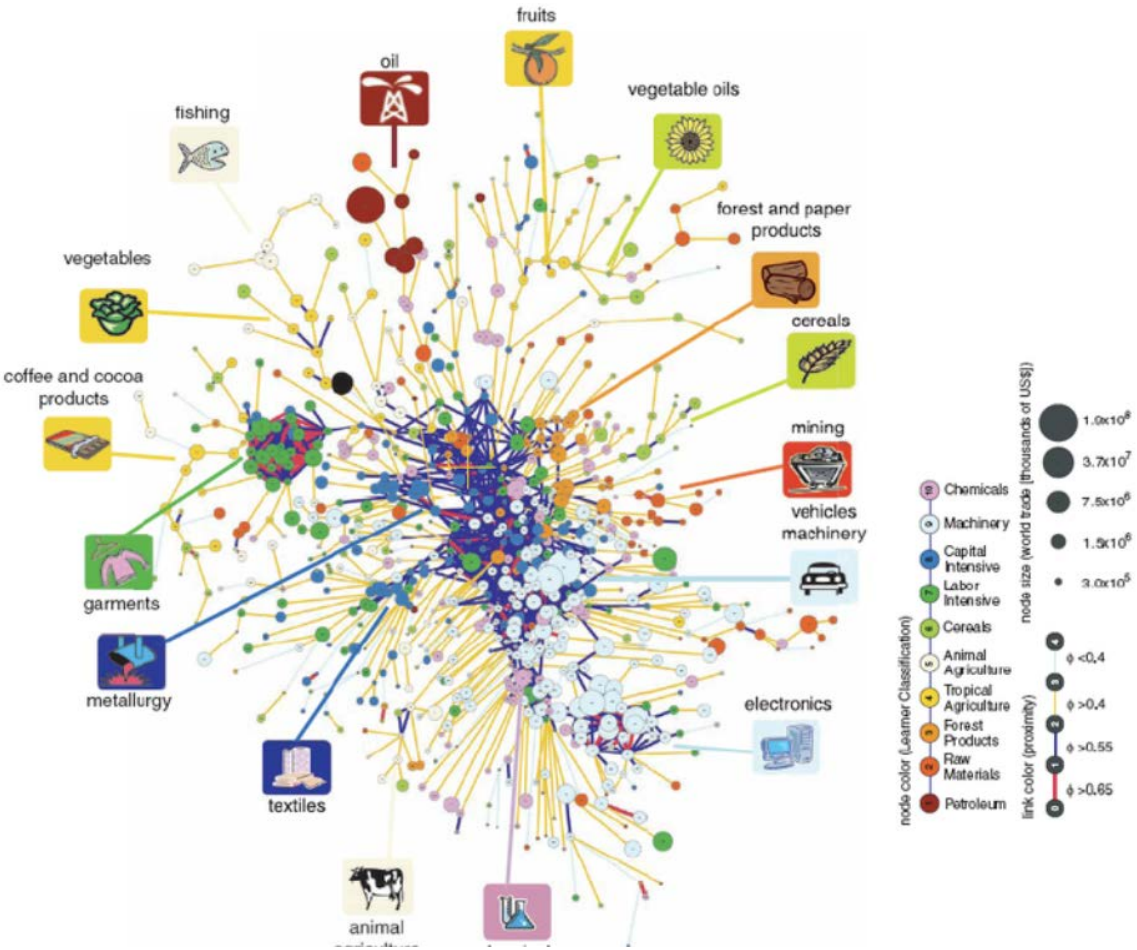
The evolution of econ. structures



The evolution of econ. structures

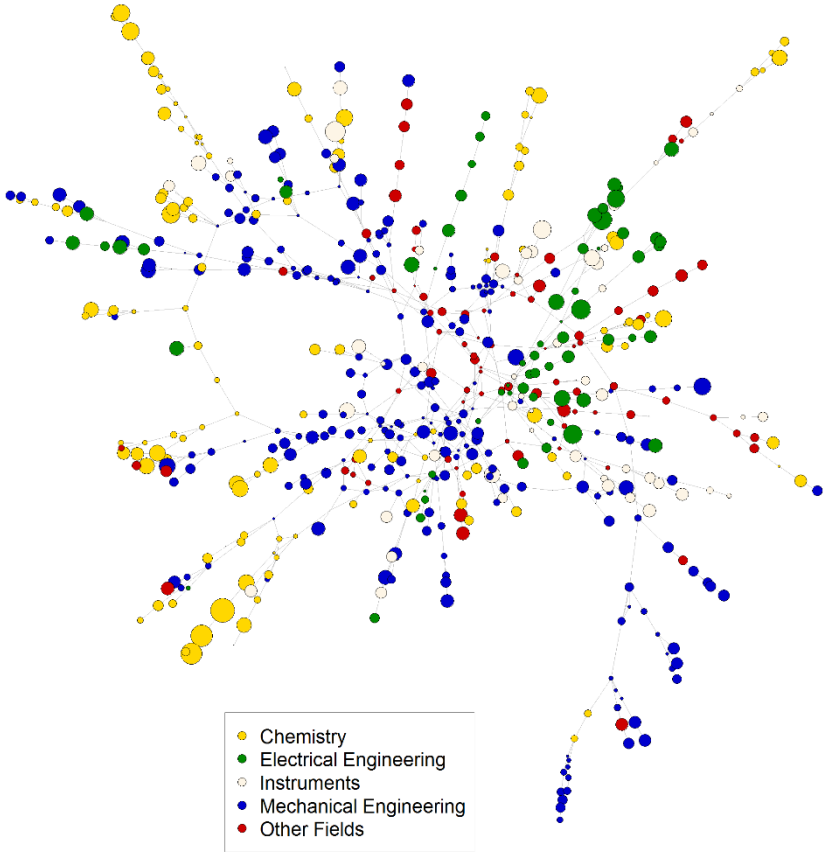


Product space & relatedness

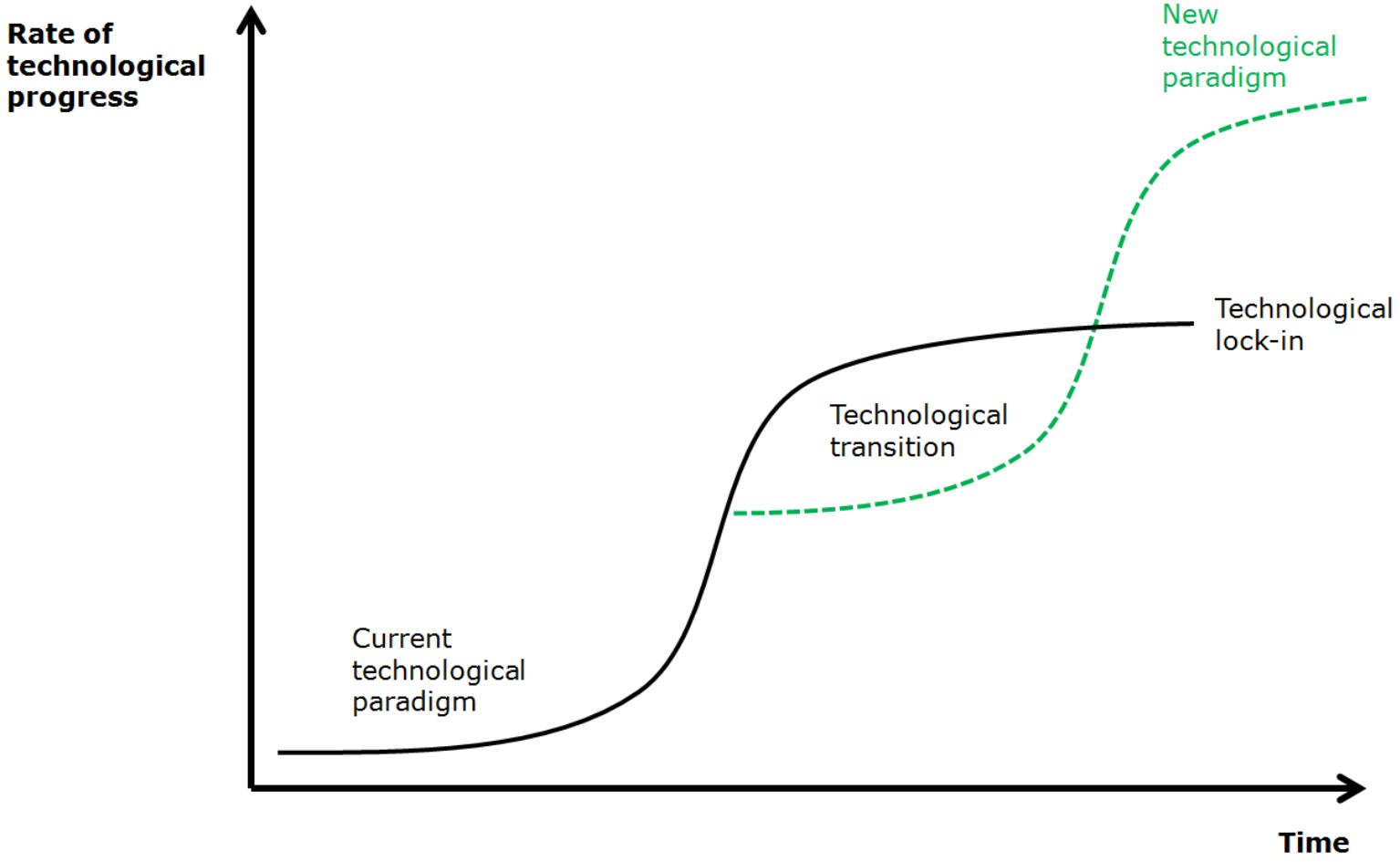


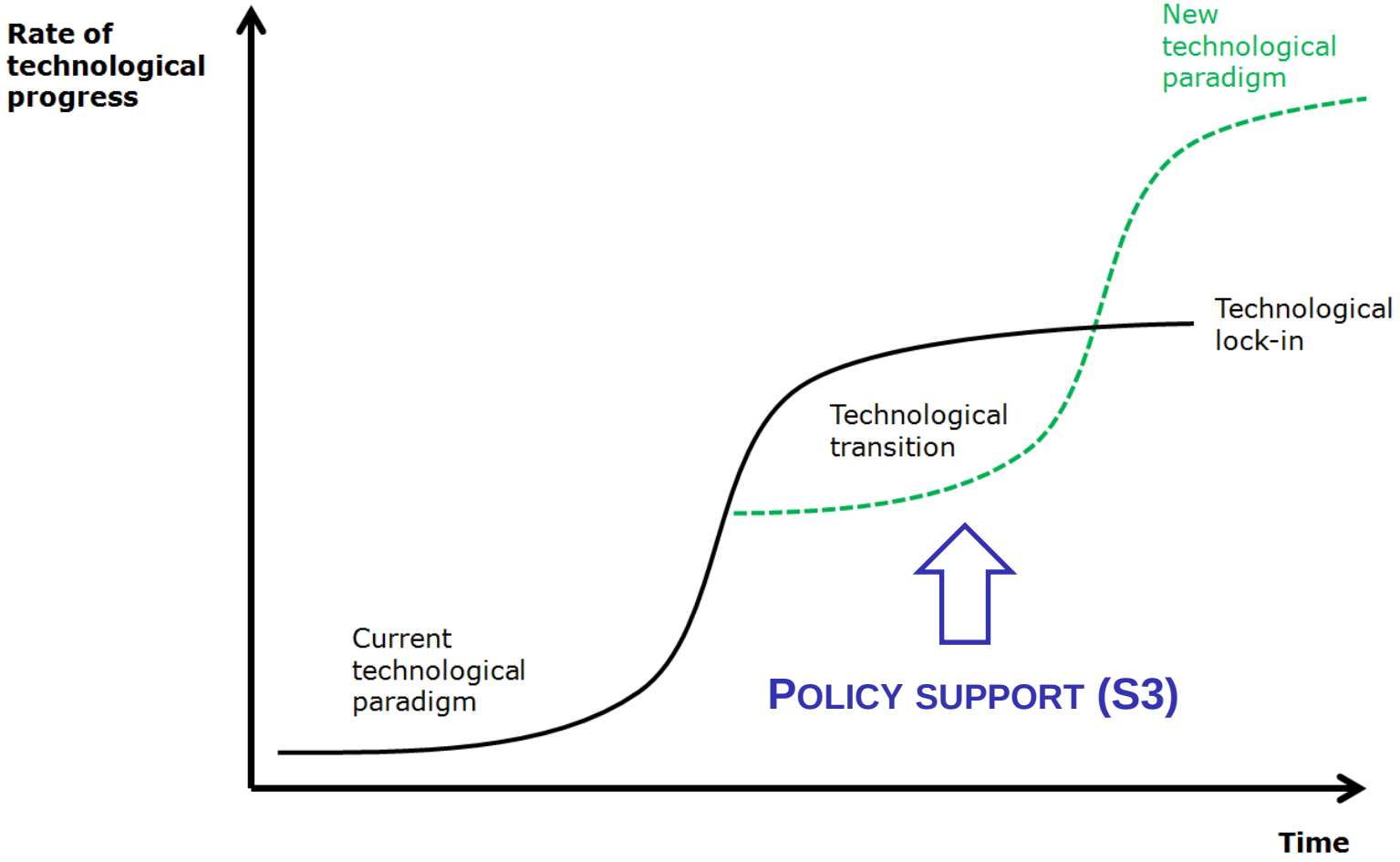
Hidalgo et al. (2007), *Science*

The technology space



Balland et al. (2018)


Rate of technological progress
New technological paradigm
Technological lock-in
Technological transition
Current technological paradigm
Time


Rate of technological progress
New technological paradigm
Technological lock-in
Technological transition
Current technological paradigm
POLICY SUPPORT (S3)
Time

RESEARCH & INNOVATION

Regional dimension of innovation

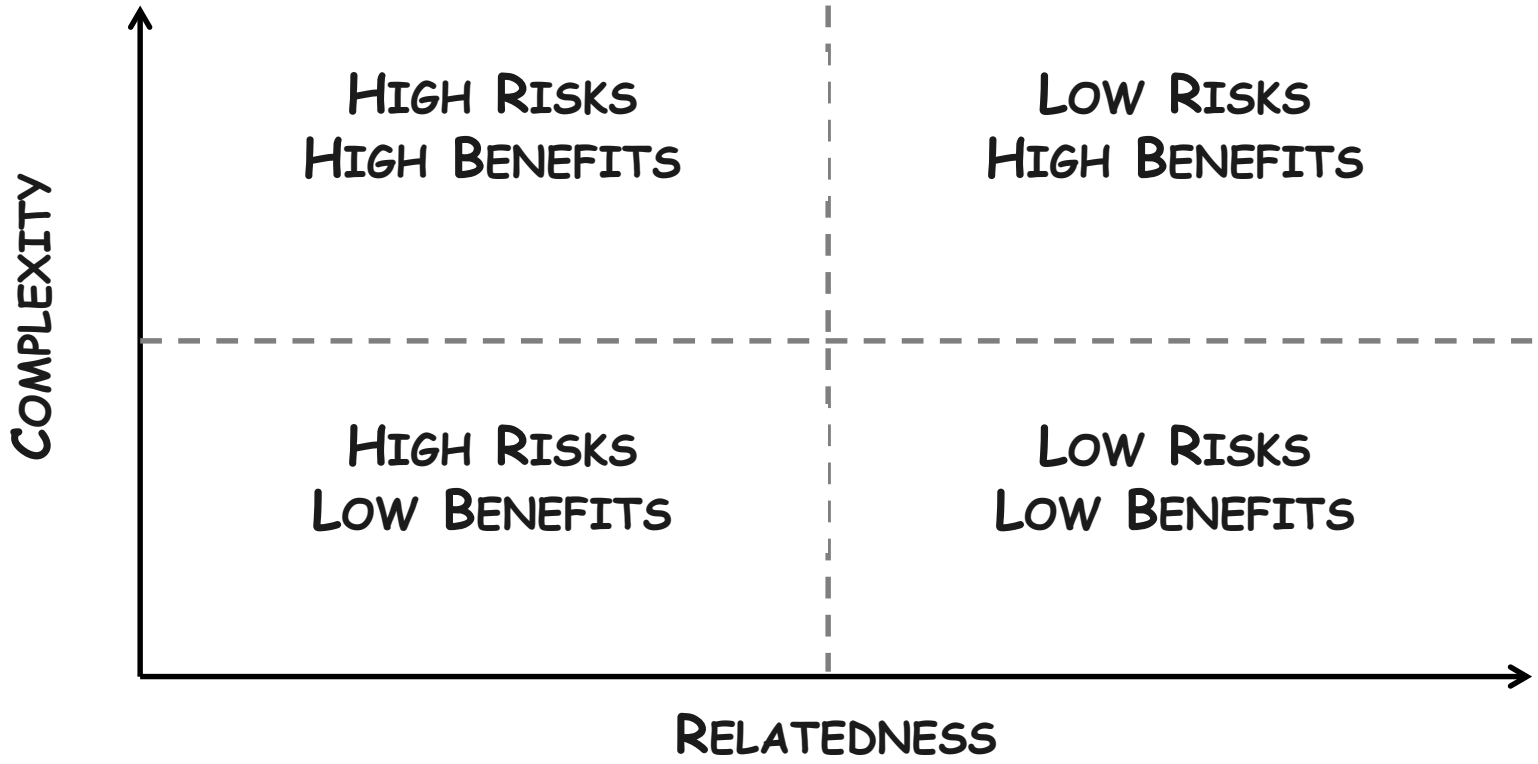
Smart specialisation

Smart specialisation is a new innovation policy concept designed to promote the efficient and effective use of public investment in research. Its goal is to boost regional innovation in order to achieve economic growth and prosperity, by enabling regions to focus on their strengths. Smart specialisation understands that spreading investment too thinly across several frontier technology fields risks limiting the impact in any one area.

A smart specialisation strategy needs to be built on a sound analysis of regional assets and technology. It should also include an analysis of potential partners in other regions and avoid unnecessary duplication. Smart specialisation needs to be based on a strong partnership between businesses, public entities and knowledge institutions – such partnerships are recognised as essential for success.

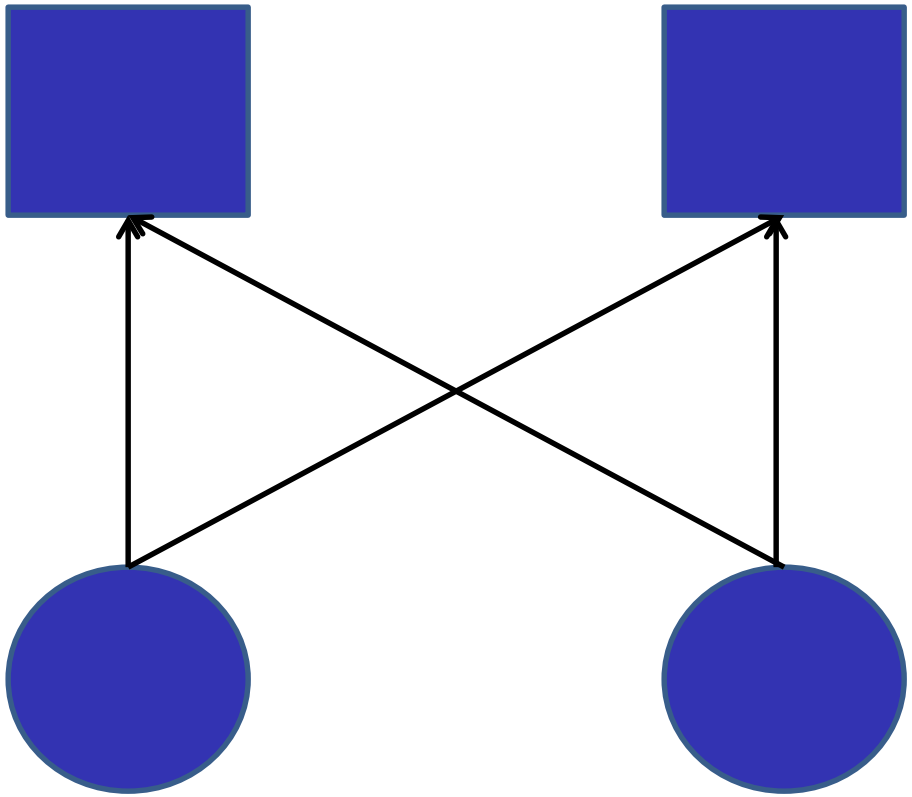
To push forward the smart specialisation concept, the Commission announced the setting up of the S³Platform in a 2010 Communication entitled 'Regional Policy contributing to smart growth in Europe 2020'. This platform aims to assist regions and Member States in developing, implementing and reviewing regional smart specialisation strategies, and help regions identify high-value added activities which offer the best chances of strengthening their competitiveness.

Smart Specialization

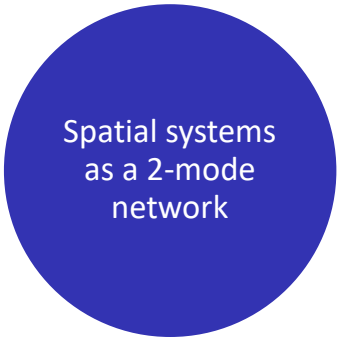


Balland et al. (2018)

The economy as a two-mode network

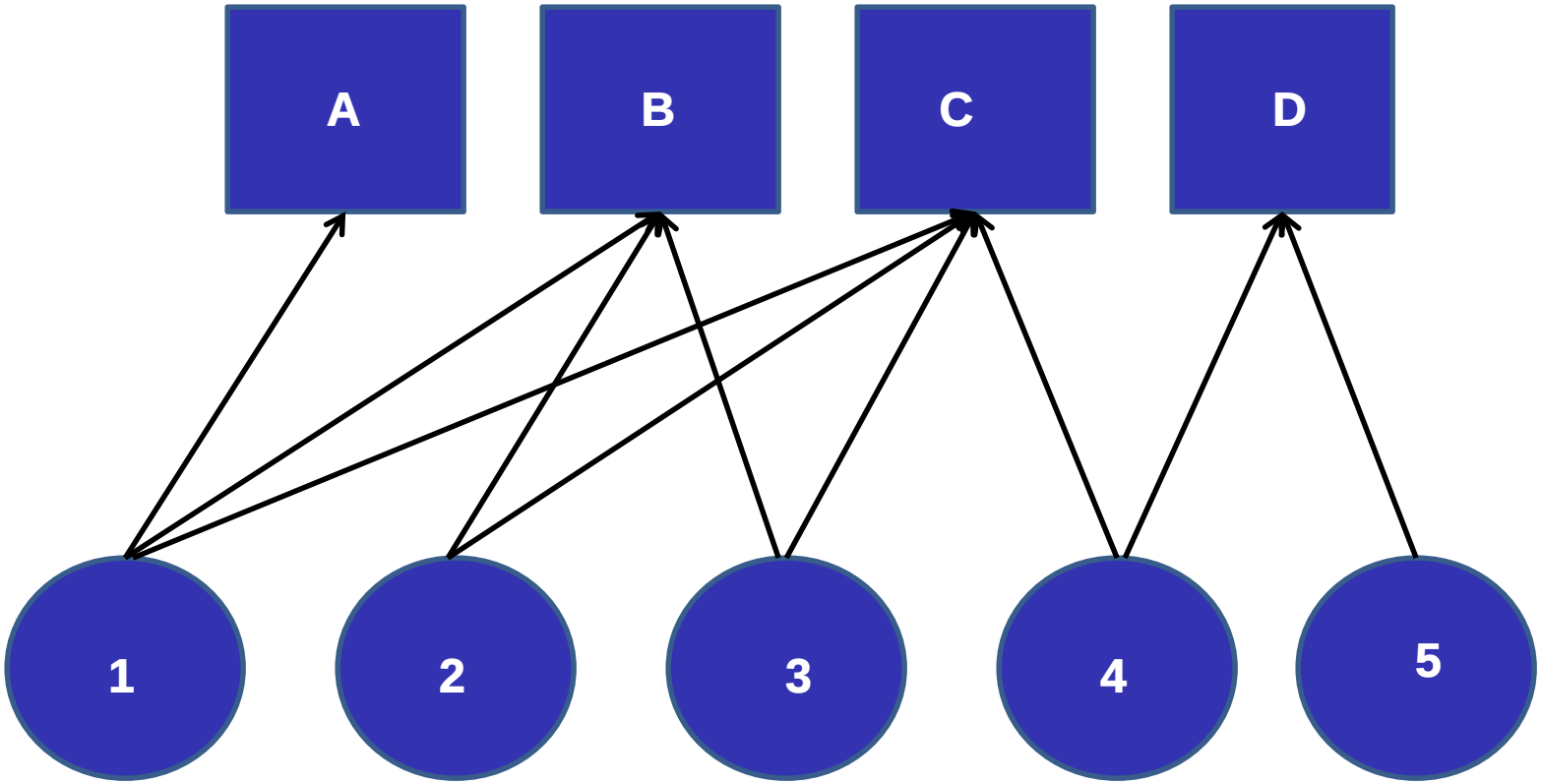


Algorithm's workflow



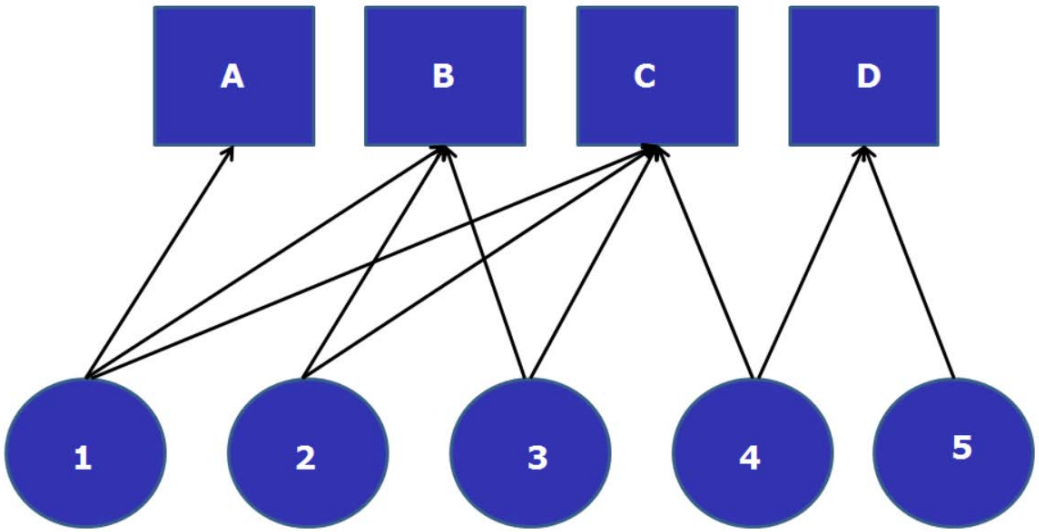
Econ. systems as 2-mode networks

Non-spatial units (economic sectors, jobs, rock band, species, sports…)



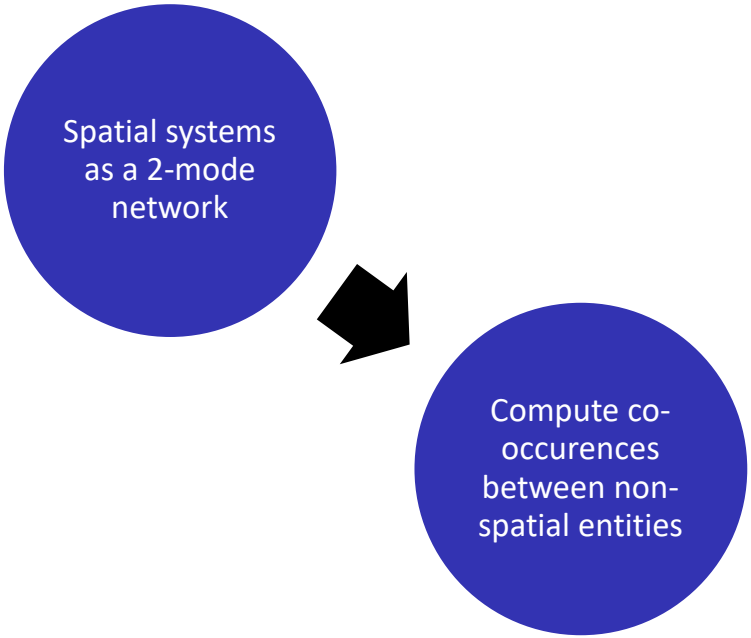
Spatial units (cities, eco-systems, states, neighborhoods…)

2-mode adjacency matrix



$$\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{cccc} A & B & C & D \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

Algorithm's workflow

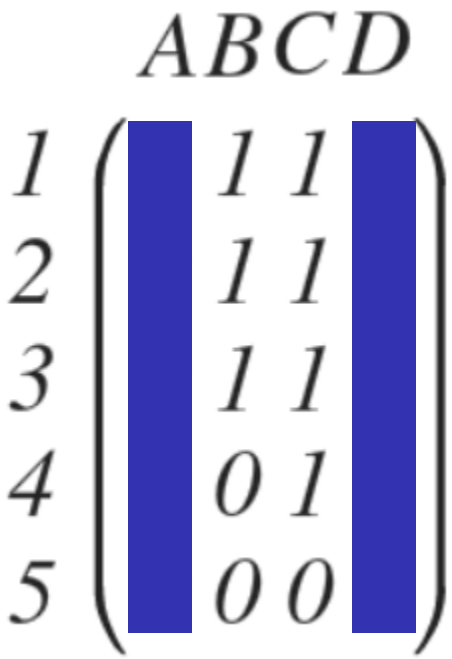


Compute co-occurences between non-sp. units

$$\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{cccc} A & B & C & D \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

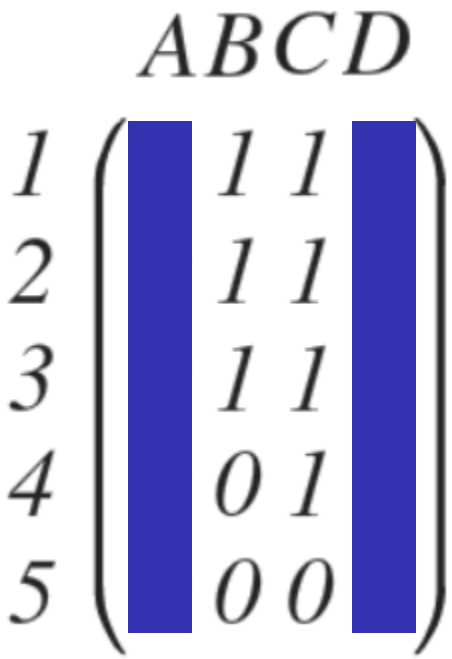
How many times B and C co-occur in the same spatial unit?

Compute co-occurences between non-sp. units



How many times B and C co-occur in the same spatial unit?
= in how many spatial unites do B and C co-exist?

Compute co-occurences between non-sp. units



How many times B and C co-occur in the same spatial unit?
= in how many spatial unites do B and C co-exist?
Response = 3 (in 1,2, and 3)

Now using matrix calculus

$$\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} A\,B\,C\,D \\ \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

$$\begin{array}{c} \\ A \\ B \\ C \\ D \end{array} \begin{array}{c} A\,B\,C\,D \\ \begin{pmatrix} & & & \\ & & & \\ & & & \\ & & & \end{pmatrix} \end{array}$$

Find the matrix of co-occurences between all non-spatial units

Transpose the matrix

$$\begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Transpose the matrix

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \qquad \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Multiply t(M) by M

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Reminder

- For matrix multiplication, the number of **columns** of the first matrix must equal the number of **rows** of the second matrix
- The product of this matrix multiplication will have the same number of **rows** as the first matrix, and the same number of **columns** as the second matrix
- In our case: a 4*5 matrix multiplied by a 5*4 matrix will give a ...matrix

$$\begin{pmatrix} 1&0&0&0&0 \\ 1&1&1&0&0 \\ 1&1&1&1&0 \\ 0&0&0&1&1 \end{pmatrix} \times \begin{pmatrix} 1&1&1&0 \\ 0&1&1&0 \\ 0&1&1&0 \\ 0&0&1&1 \\ 0&0&0&1 \end{pmatrix} = \begin{pmatrix} \quad & \quad & \quad & \quad \end{pmatrix}$$

Multiply t(M) by M

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} & & & \\ & & & \\ & & & \\ & & & \end{pmatrix}$$

Multiply t(M) by M

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & & & \\ & & & \\ & & & \\ & & & \end{pmatrix}$$

*1*1+0*0+0*0+0*0+0*0 = 1*

Multiply t(M) by M

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 1 & & \\ & & & \\ & & & \\ & & & \end{pmatrix}$$

*1*1+0*1+0*1+0*0+0*0 = 1*

Multiply t(M) by M

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 & 0 \\ 1 & 3 & 3 & 0 \\ 1 & 3 & 4 & 1 \\ 0 & 0 & 1 & 2 \end{pmatrix}$$

*1*1+1*1+1*1+0*1+0*0 = 3*

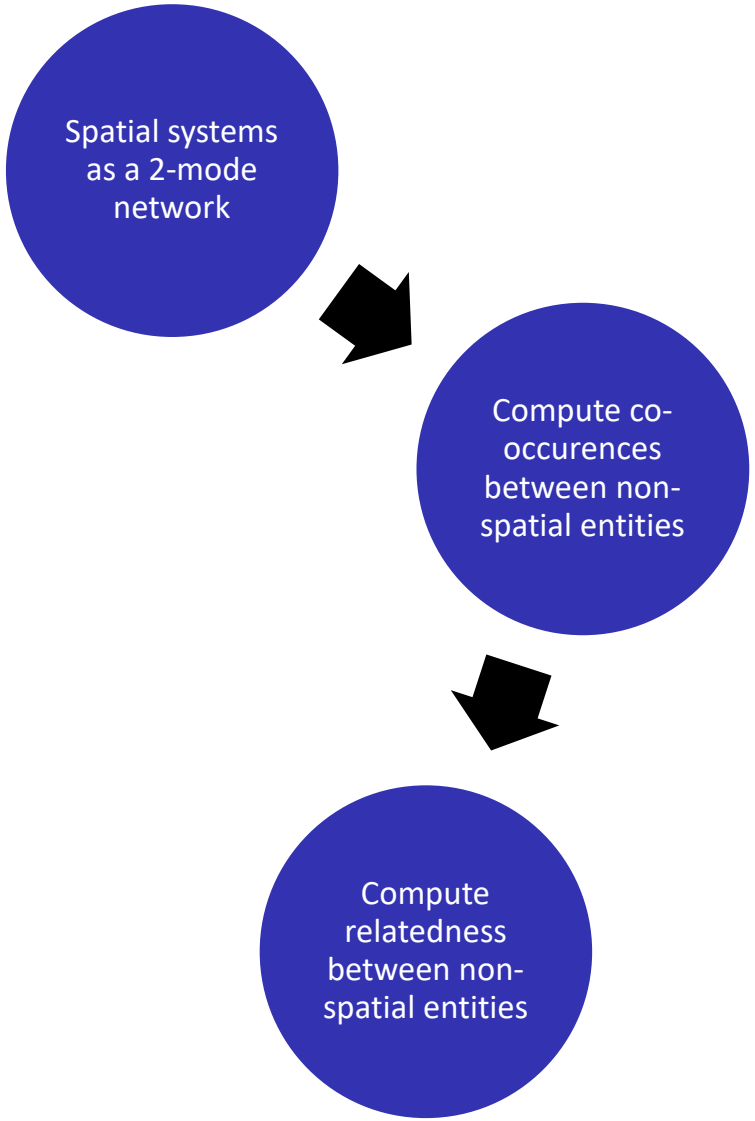
A matrix of co-occurences

$$\begin{pmatrix} 1 & 1 & 1 & 0 \\ 1 & 3 & 3 & 0 \\ 1 & 3 & 4 & 1 \\ 0 & 0 & 1 & 2 \end{pmatrix}$$

A matrix of co-occurences (diag = 0)

$$\begin{pmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 3 & 0 \\ 1 & 3 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

Algorithm's workflow



Normalize co-occurences

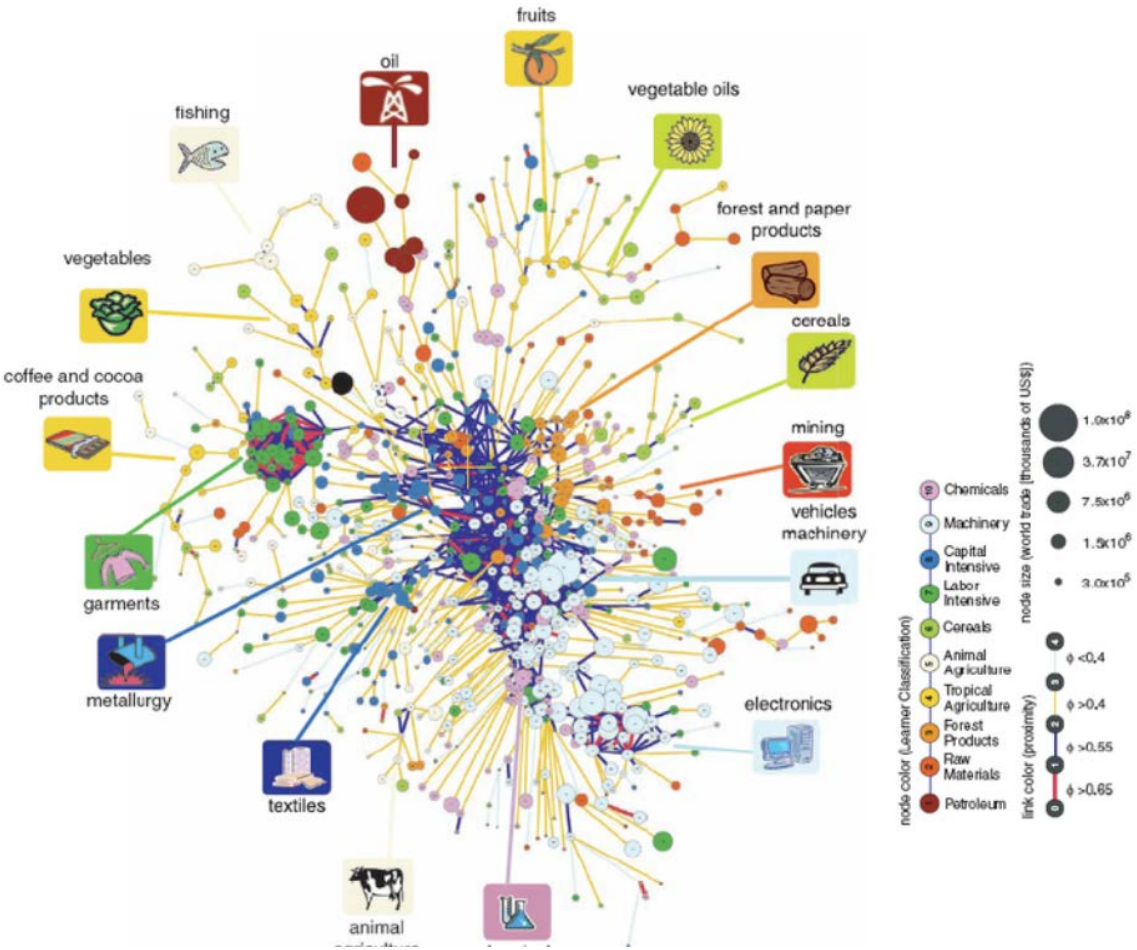
$$\begin{pmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 3 & 0 \\ 1 & 3 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

$$\frac{observed \;\; co\text{-}occurences}{expected \;\; co\text{-}occurences}$$

Normalizing co-occurences: relatedness

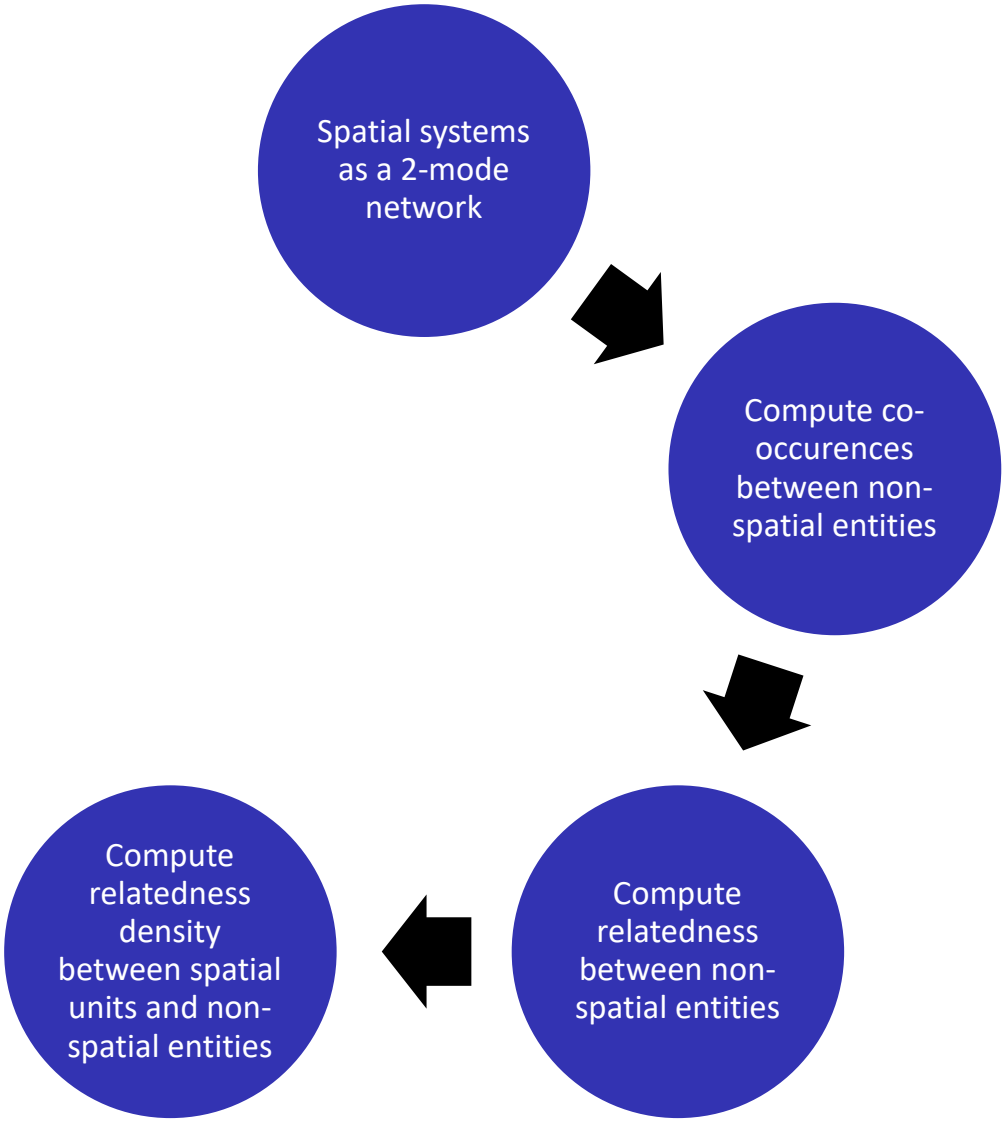
$$if \quad \frac{observed \;\; co\text{-}occurences}{expected \;\; co\text{-}occurences} > 1 \;\; \text{--> related}$$

Product space & relatedness



Hidalgo et al. (2007), *Science*

Algorithm's workflow



The density of related technologies

$$D_{i,c,t} = \frac{\sum_i x_i \varphi_{ij}}{\sum_i \varphi_{ij}} \times 100$$

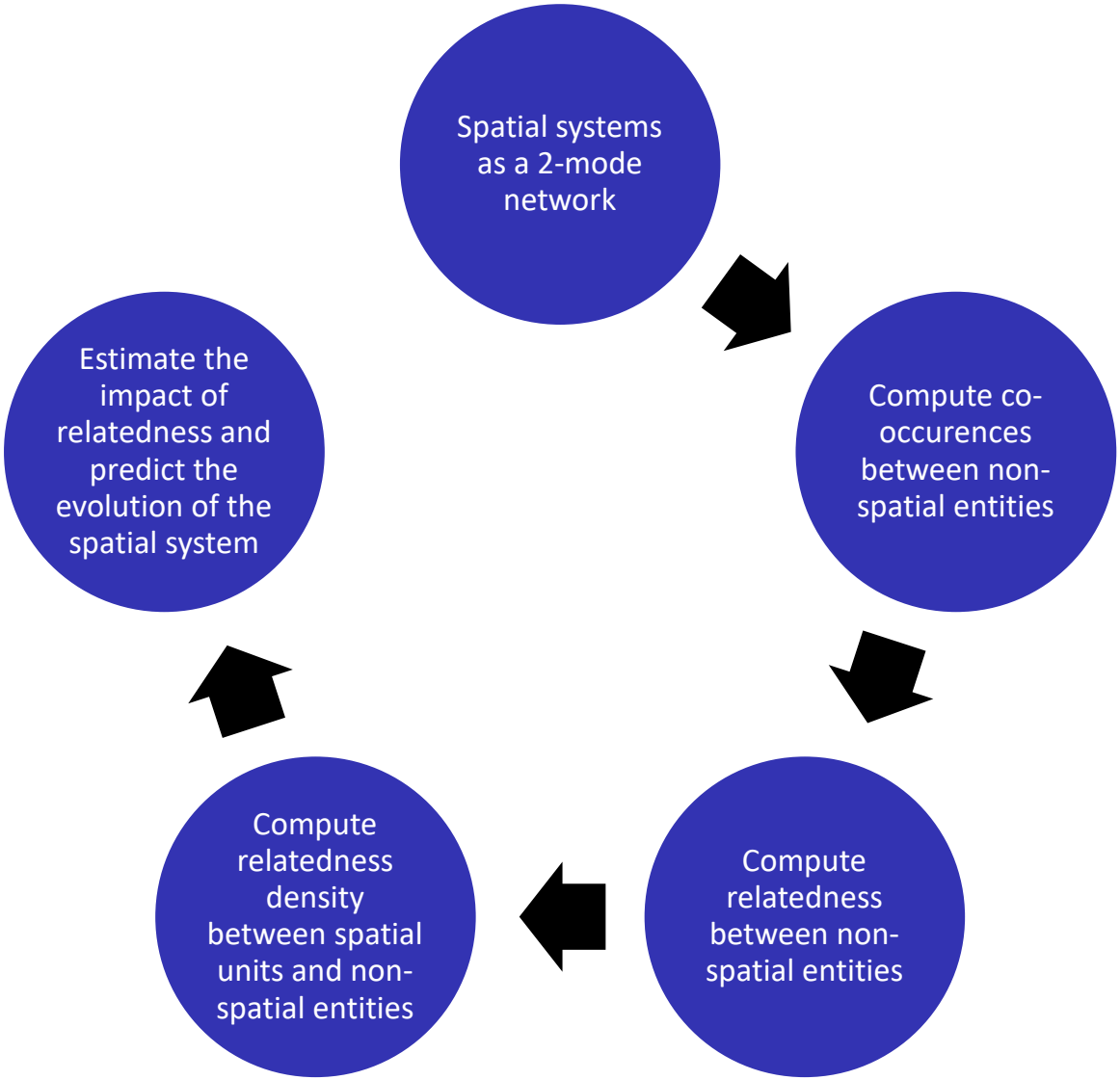
City (MSA)	Tech. class (3 digits)	Density (%)
New-York	428	10
New-York	524	100
Los Angeles	428	80
Los Angeles	524	0
…	…	…

*The **Density Index** measures the relatedness of a new technology to the pre-existing set of technologies produced in this particular city.*

Relatedness density

$$
\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array}
\begin{array}{c}
\begin{array}{cccc} A & B & C & D \end{array} \\
\begin{pmatrix}
100 & 100 & 80 & 100 \\
100 & 75 & 60 & 100 \\
100 & 75 & 60 & 100 \\
50 & 75 & 20 & 100 \\
0 & 0 & 20 & 0
\end{pmatrix}
\end{array}
$$

Algorithm's workflow



The econometric model

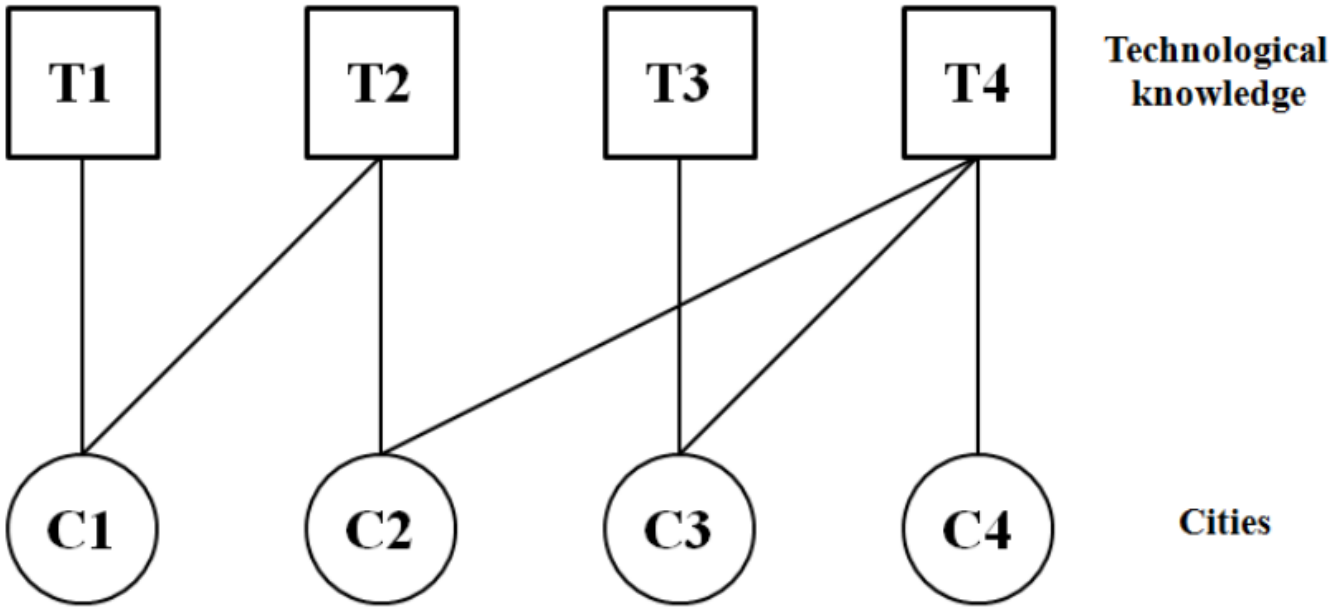
$$Entry_{i,c,t} = \beta_1 Density_{i,c,t-1} + \beta_2 City_{c,t-1} + \beta_3 Techno_{i,t-1} + \phi_c + \psi_i + \alpha_t + \varepsilon_{i,c,t}$$

***Entry*$_{i,c,t}$ = 1** *if a technology i that did not belong to the portfolio of the city c in time t-1 enters its technology space in time t.*

Results

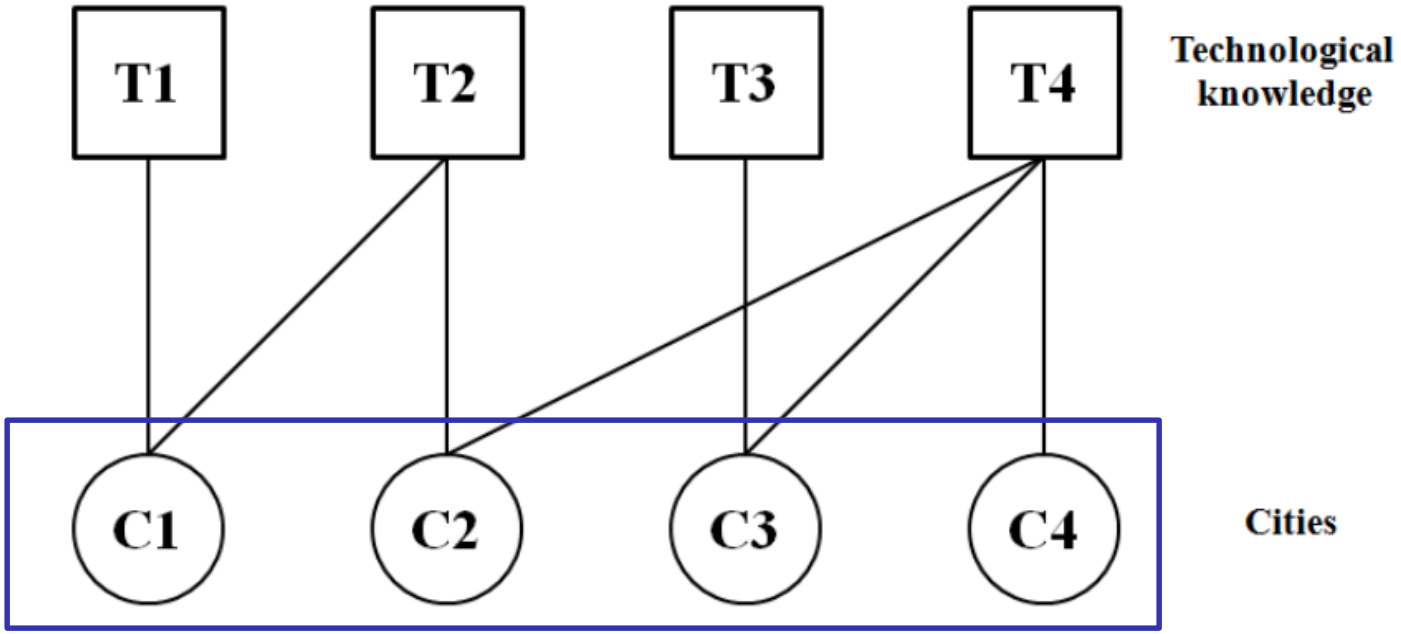
Dependent variable is: $Entry_t$	Model 1 Rel. density	Model 2 City variables	Model 3 Tech. variables	Model 4 Full model	Model 5 Full model (F.E.)
$Relatedness\ density_{t-1}$	0.00515979**			0.00373407**	0.00271463**
	(0.00012770)			(0.00014135)	(0.00016884)
$Log\ (Employment)_{t-1}$		0.04934166**		0.03611889**	0.04633250**
		(0.00286818)		(0.00247147)	(0.00782869)
$Population\ density_{t-1}$		0.00001106		0.00002520**	−0.00021341**
		(0.00000997)		(0.00000843)	(0.00003836)
$Inventive\ capacity_{t-1}$		0.07718815**		0.03883926**	−0.08487966**
		(0.01294204)		(0.0078352020)	(0.01505564)
$Tech.\ Specialization_{t-1}$		−0.00089296**		−0.00047160**	0.00005120
		(0.00011548)		(0.00009315)	(0.00011022)
$MSA\ growth\ rate_{t-1}$		0.04443962**		0.04032813**	0.00865397**
		(0.00355534)		(0.00353667)	(0.00298386)
$Log\ (Income\ per\ employee)_{t-1}$		−0.07584685**		−0.10127439**	0.00368879
		(0.00441610)		(0.00538561)	(0.01663469)
$Log\ (Nb.\ Inventors)_{t-1}$			0.02658895**	0.02324554**	0.00159990
			(0.00197752)	(0.00183672)	(0.00246612)
$Tech.\ concentration_{t-1}$			−0.00102840**	−0.00010693	0.00041990 *
			(0.00014936)	(0.00011541)	(0.00016760)
$Date\ established_{t-1}$			−0.00056684**	−0.00042520**	−0.00330620**
			(0.00007012)	(0.00005456)	(0.00017699)
$Tech.\ growth\ rate_{t-1}$			0.01423964**	0.02183910**	0.01141729**
			(0.00233334)	(0.00285492)	(0.00260757)
Constant	0.09258502**	0.09296771**	0.09019069**	0.08909252**	0.11108572**
	(0.00194271)	(0.00378306)	(0.00398429)	(0.00183778)	(0.01040890)
City F.E.	No	No	No	No	Yes
Technology F.E.	No	No	No	No	Yes
Period F.E.	No	No	No	No	Yes
R^2	0.11	0.04	0.02	0.13	0.16
N	748,458	653,660	656,618	572,550	572,550

Spatial dynamics of knowledge



Balland and Rigby (2016), *Economic Geography*

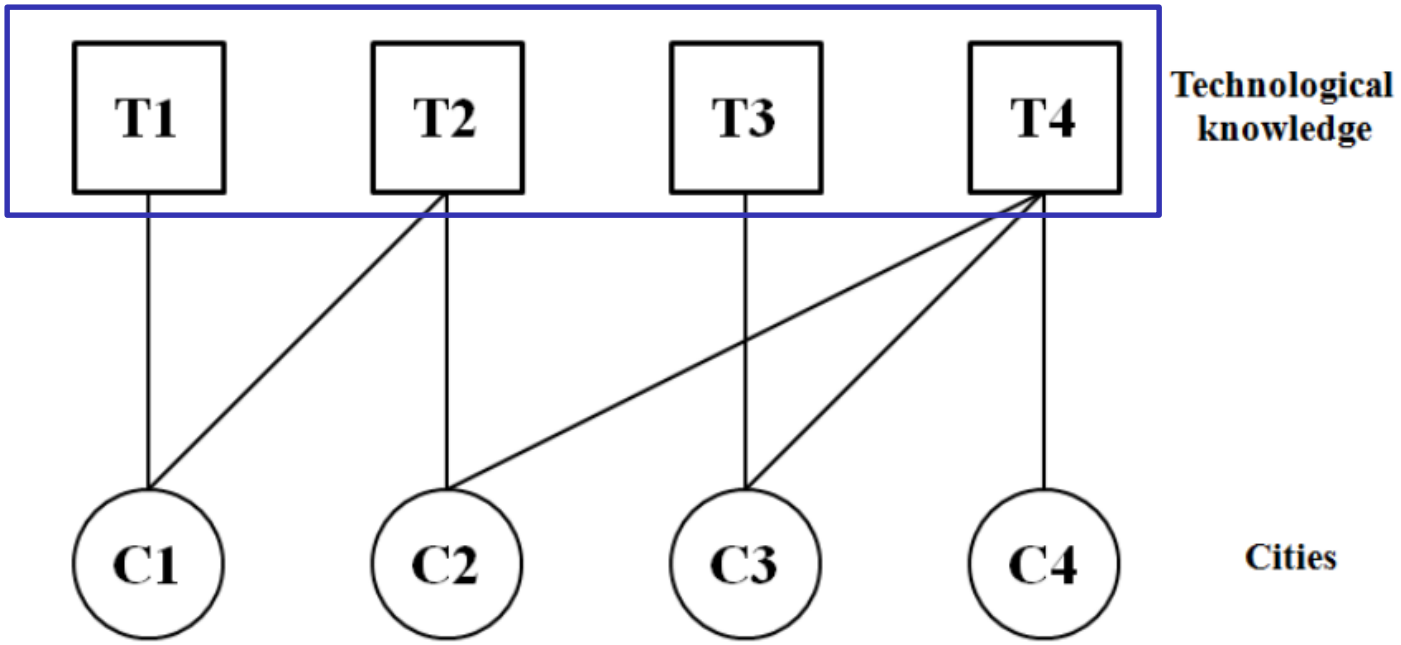
Diversity



Balland and Rigby (2016), *Economic Geography*

Diversity is the degree centrality of the spatial units

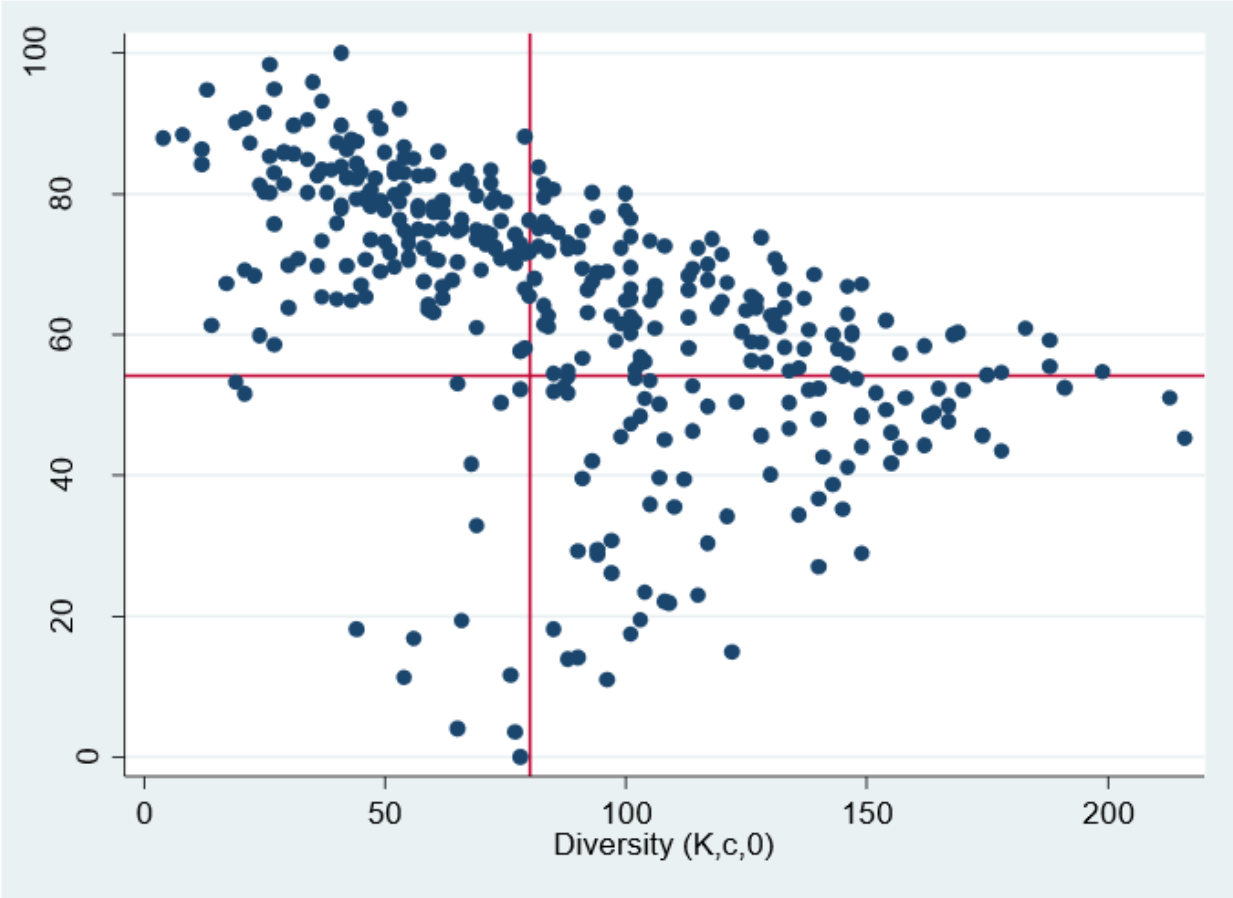
Ubiquity



Balland and Rigby (2016), *Economic Geography*

Ubiquity is the degree centrality of the econ/tech units

Diversity and average ubiquity



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