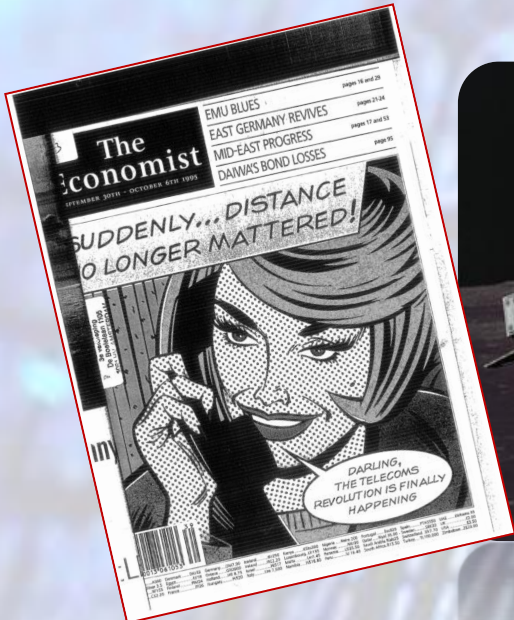
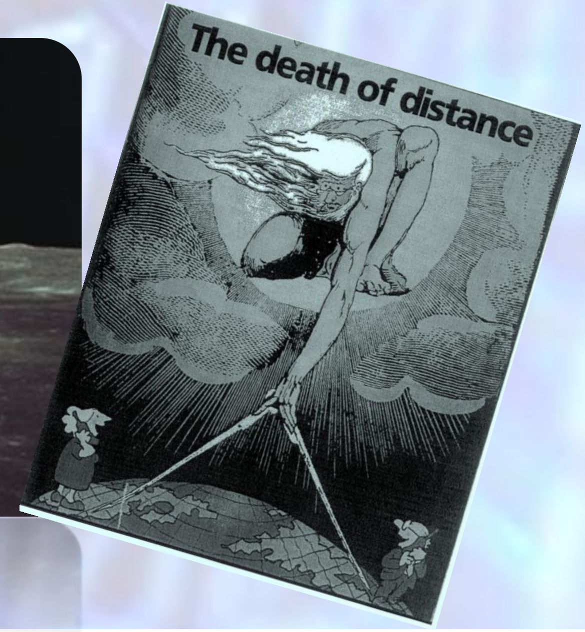
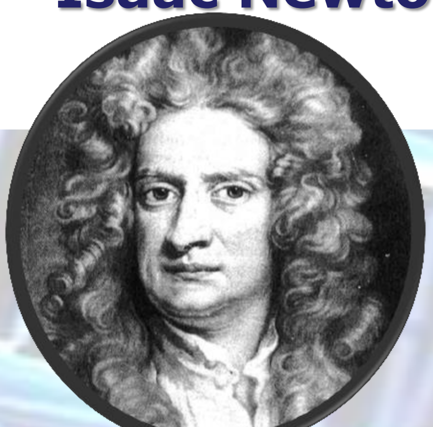


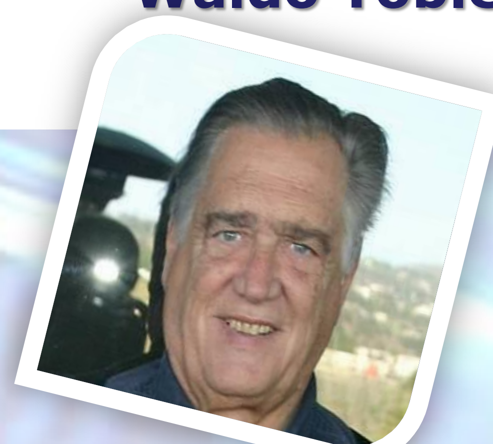


IT'S A SMALL WORLD
PETER NIJKAMP

Isaac Newton



Waldo Tobler



I. Introduction

Dilemma 1: Gravitational Principle in Physical World

vs.

Digital Connectivity in a Global Virtual World

Trends in Spatial Dynamics and Trade:

- Online Services
- Electronic Orders (e.g. Call Centers)
- Business Services (Electronic Mail)
- Virtual Realities

Dilemma 2: The Death of Distance (Requiem for Von Thuenen)

vs.

The End of Trade (Requiem for Hermes)

- **Isaac Newton (1687 - 1692/3) → Philosophiae Naturalis Principia Mathematica: *Universal Gravitational Principle***

  "It is inconceivable that inanimate Matter should, ….., operate upon, and affect other matter without mutual Contact"

  without the Mediation of Something else, which is not material

"Gravity must be caused by an Agent acting constantly according to certain laws".

- **Waldo Tobler (1970) → *First Law of Geography***

  "Everything is related to everything else, but near things are more related than distant things".

II. History: Gravity, Entropy, Discrete Choice

- Carey (1858) – ***Principles of Social Science***
- Ravenstein (1885) – ***The Laws of Migration***
- Janowski (1908)
- Isard (1960)
- Tinbergen / Linnemann → ***Gravity Model***

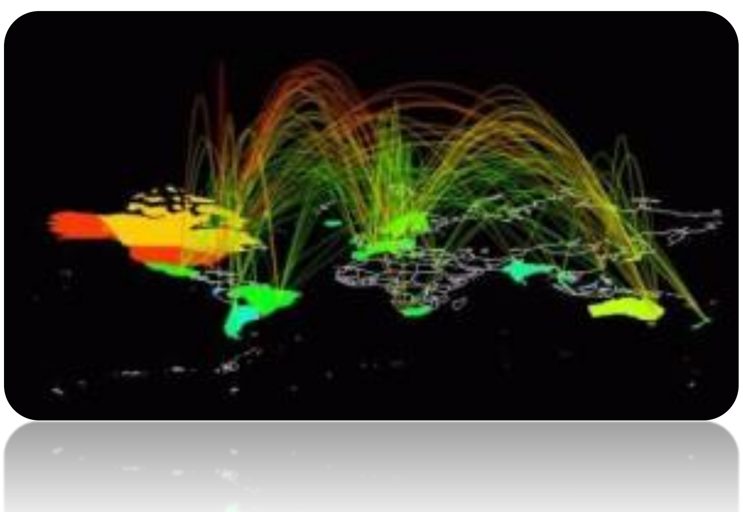
  - Trade
  - Transport
  - Migration
- Alonso (1978) – ***A General Theory of Movement***
- Wilson - ***Entropy*** (Spatial Interaction Models)
- McFadden / Kahnemann - ***Discrete Choice Models***
- Reggiani / Nijkamp - ***Behavioural Economic Equivalence of Gravity, Entropy, and Discrete Choice***
- Krugman - ***NEG***: Agglomeration (Mass) + Distance Friction (Costs)
- Cairncross - Unpleasant surprise due to ***'The Death of Distance'***

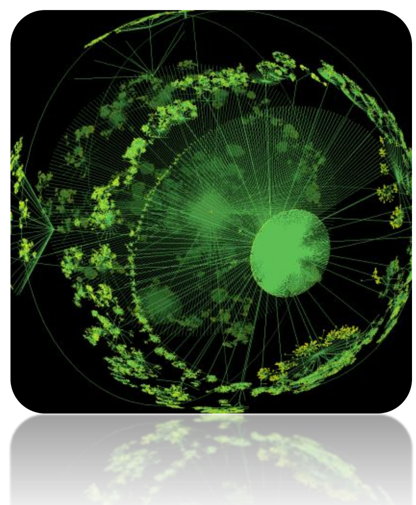
Challenge: The Spatial Economics/Econometrics of the Virtual World

III. Cyberplace and Cyberspace: General Framework

Background

- The new spatial form of the *space of flows* (Castells, 1996).
- Virtual geography: cyberplace (CP) *vs.* cyberspace (Batty, 1997).
- Internet geography or cybergeography.
- The Internet is *not* a homogeneous system equally spread around places (Gorman and Malecki, 2000).
- The placeless *cyberspace* depends on real world's fixities (Kitchin, 1998a and 1998b) found on *cyberplace*, which is the infrastructural reflection of the cyberspace on the physical space (Batty, 1997).
- More than one Internet geography (Zook, 2006).





Economic Geography of the Internet Infrastructure: Examples

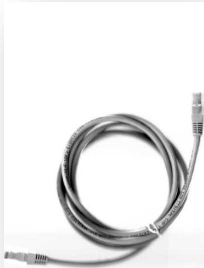
Study	Region	Spatial unit	Indicator	Time
Wheeler and O'Kelly 1999	USA	city, backbone networks	Tc	1997
Gorman and Malecki 2000	USA	city	tc, tb, network distance	1998
Moss and Townsend 2000	USA	city	Tb	1997-1999
Malecki and Gorman 2001	USA	city	tc, tb number of hops	1998
Townsend 2001a	World	city	Tb	2000
Townsend 2001b	USA	city	tc, tb, domains	1997, 1999
Malecki 2002a	Europe	city	tc, tb, colocation points	2000
	Europe, Asia, Africa, Americas	continent	peering points	2000
	USA	city	tc, tb, b colocation points	1997-2000
O'Kelly and Grubesic 2002	USA	backbone networks, city	c, tc	1997-2000
Gorman and Kulkarni 2004	USA	city	tb,tc, c	1997-2000
Malecki 2004	USA	city	tb, b	1997-2000
Rutherford et al. 2004	Europe	city	b, tb, tc	2001
Schintler et al. 2004	Europe, USA	city	Tc	2001, 2003
Rutherford et al. 2005	Europe	city	c, tc, tb	2001, 2003
Devriendt et al 2008	Europe	city	intercity links, IXPs	2001, 2006
Devriendt et al 2010	Europe	city	intercity links, IXPs	2008
Rutherford forthcoming	Europe	city	c, tc, tb	2001, 2004
Tranos and Gillespie 2008	Europe	city	tb, tc	2001
Tranos forthcoming	Europe	city	c, b, tc, tb	2001-2006
Malecki and Wei 2009	World	country, city	tc, tb	1979-2005

b = bandwidth, c = connectivity (i.e. number of connections), t = total; *(Tranos and Gillespie 2011)*

III. Cyberplace and Cyberspace: General Framework

How to approach cyber networks?

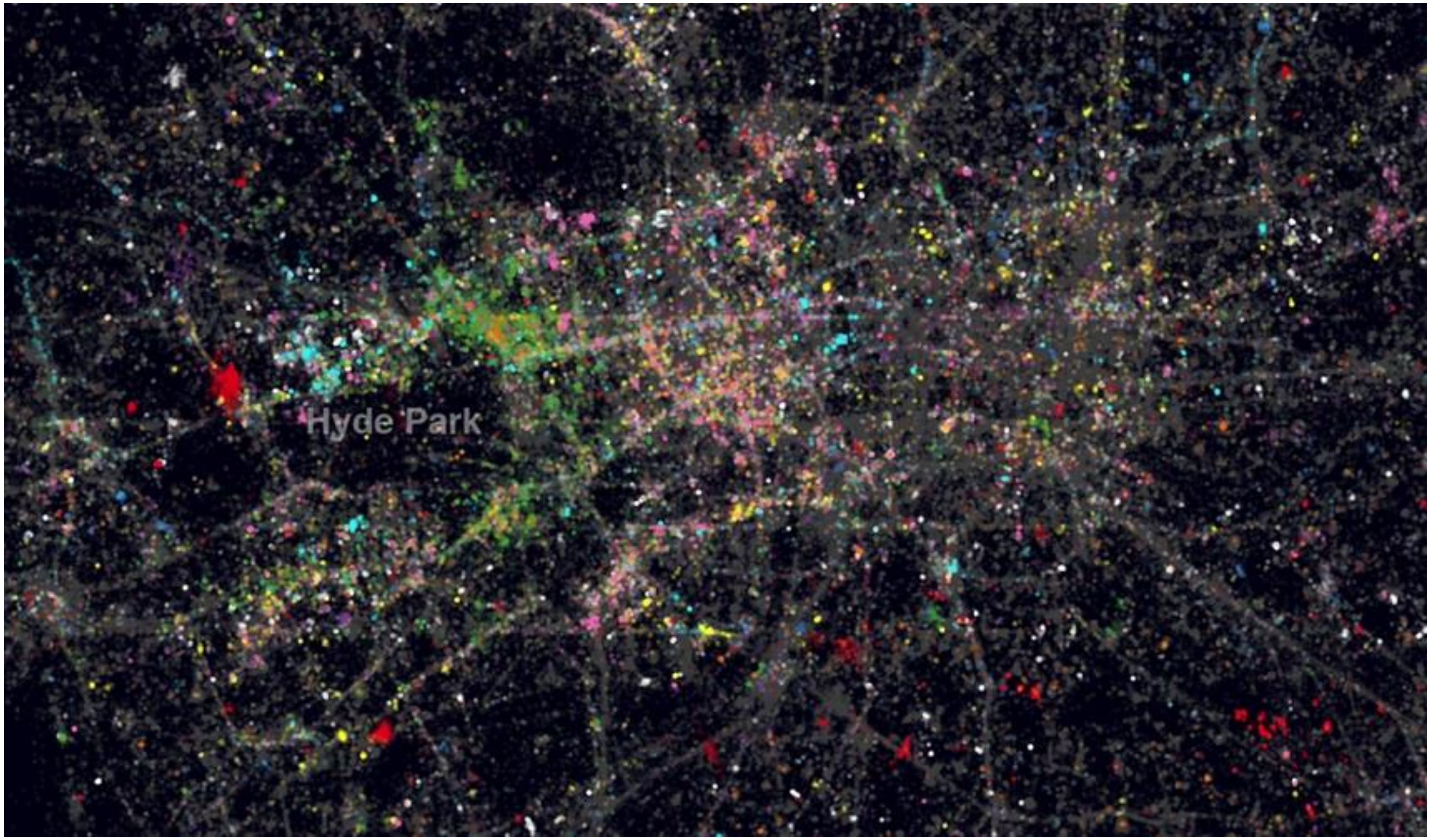
- Explore the complex nature of digital communication networks
- Test empirically the impact of physical distance and relational proximities on the formation of CP using gravity models



IV. The Complex Nature of Digital Communication Networks

- A new analytical departure based on the *new science of networks* (Barabási, 2002; Buchanan, 2002; Watts 2003, 2004), with a focus on large-scale real world networks and their universal, structural and statistical properties leading to a better understanding of the underlying mechanisms governing the emergence of these properties (Newman, 2003)

Network of Twitter Languages in London

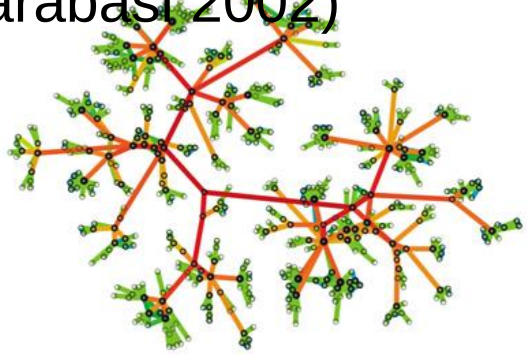


IV. The Complex Nature of Digital Communication Networks

Two main streams of complex network analysis:

- A more ***descriptive*** one, which focuses on various network measures and compares real networks with theoretical models such as *scale-free* networks, mostly using the (cumulative) degree distribution (e.g. Gorman and Kulkarni 2004; Schintler et al 2004; Regianni et al 2010; Tranos 2011)

- A ***hard modelling explanatory*** one, which is based on modeling exercises in order to simulate the evolution of empirical networks, based on *stochastic* approaches and *statistical physics* (e.g. Barabási and Albert 1999; Albert and Barabási 2002)



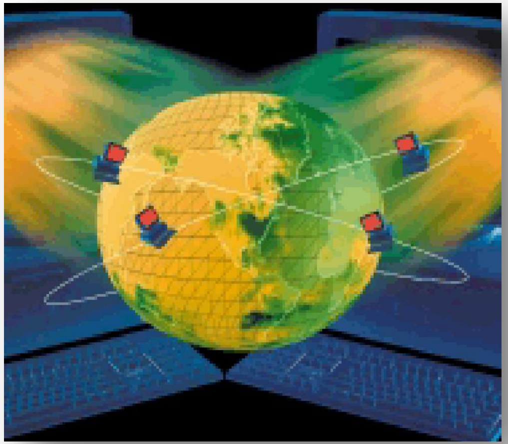
IV. The Complex Nature of Digital Communication Networks

Operational approach:

Structural analysis of an IP network

- Intra-european city-to-city links aggregated at NUTS3 level
- Infrastructural network: inter-city digital links operating at the level 3 of the OSI system
- Observations over time (2005-2008)
- Fraction of the overall Internet: based on traceroutes

data source: DIMES Project 2011



Intra-European IP links, 2007

V. The Complex Nature of Digital Communication Networks

Nodes degree distribution

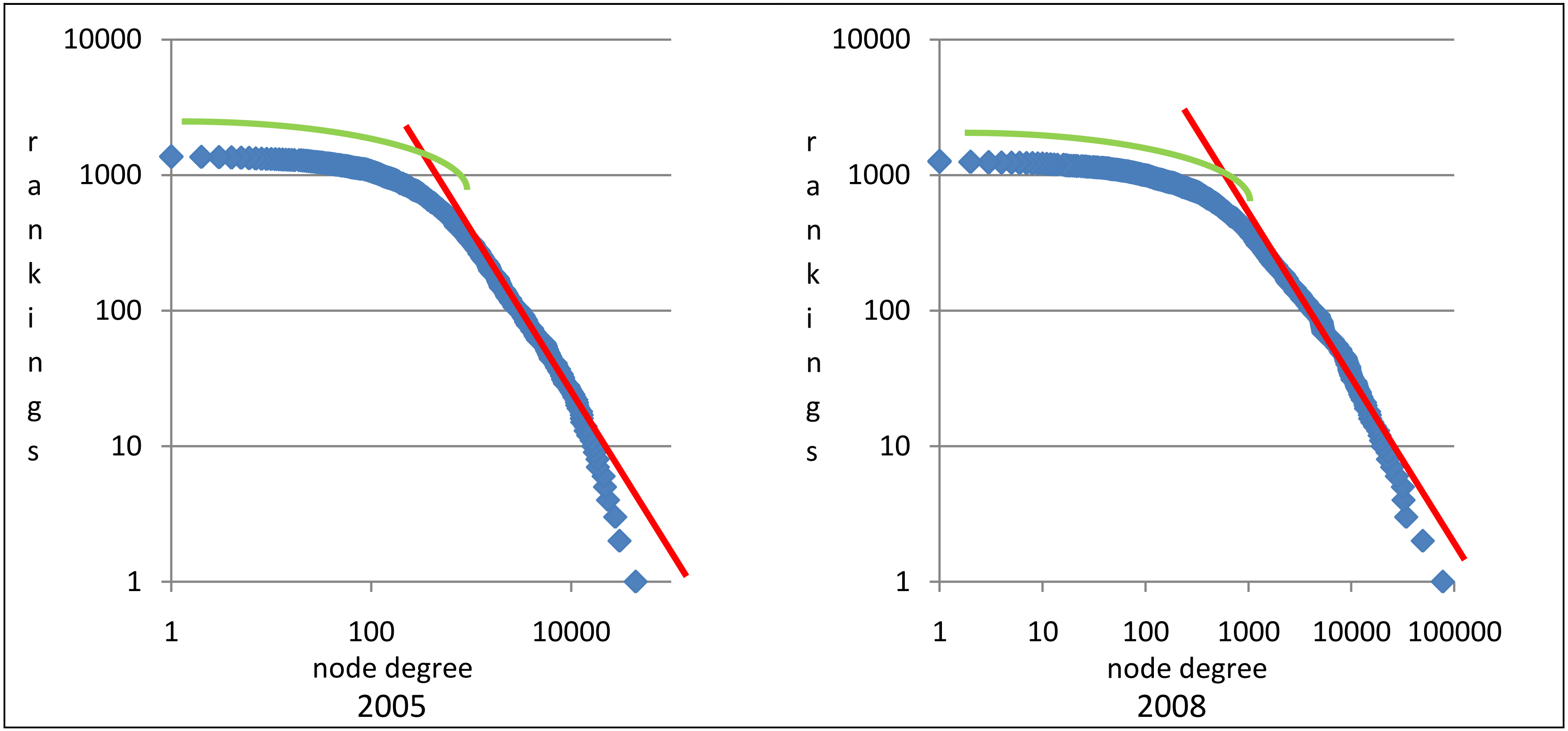


Figure 1: Cumulative degree distribution of NUTS-3 regions based on IP links

Two different curves for both years:

- a **straight line** indicating a power law for the most-connected nodes of the IP network
- a **curve** suggesting an exponential law for the least-connected nodes

V. The Complex Nature of Digital Communication Networks

Curve estimations (OLS and log transformations)

Three hypothesis:

exponential $p(x) \propto e^{-\alpha x}$

power $p(x) \propto x^{-\alpha}$

power with cutoff (Tanner function) $p(x) \propto x^{-\alpha} e^{-\lambda x}$

		Exponential		Power		Tanner function		
	N	R^2	Coef.	R^2	Coef.	R^2	Power Coef.	Exp. Coef.
2005	1376	0.679	0.0003	0.733	-0.481	**0.909**	-0.323	-0.0002
2008	1276	0.632	0.0002	0.712	-0.435	**0.889**	-0.305	-0.0001

VI. Internet Infrastructure and Proximities

Empirical testing of the impact of different types of proximities on the formation of CP

- *Starting point:* the first law of geography and the importance of physical distance on CP
- *Proximity* is not limited only on physical distance
- *French School of Proximity*: the spatial dimension of enterprises and organizations
- Its *main objective*: to incorporate space and other territorial proximity elements to better understand the dynamics of innovation (Torre and Gilly 2000)
- *Evolutionary economic geography:* the notion of proximity and its different components are juxtaposed with ideas about knowledge transfer and creation, tacit knowledge, and learning regions (Boschma 2004)

VI. Internet Infrastructure and Proximities

Empirical testing of the impact of different types of proximities on the formation of CP

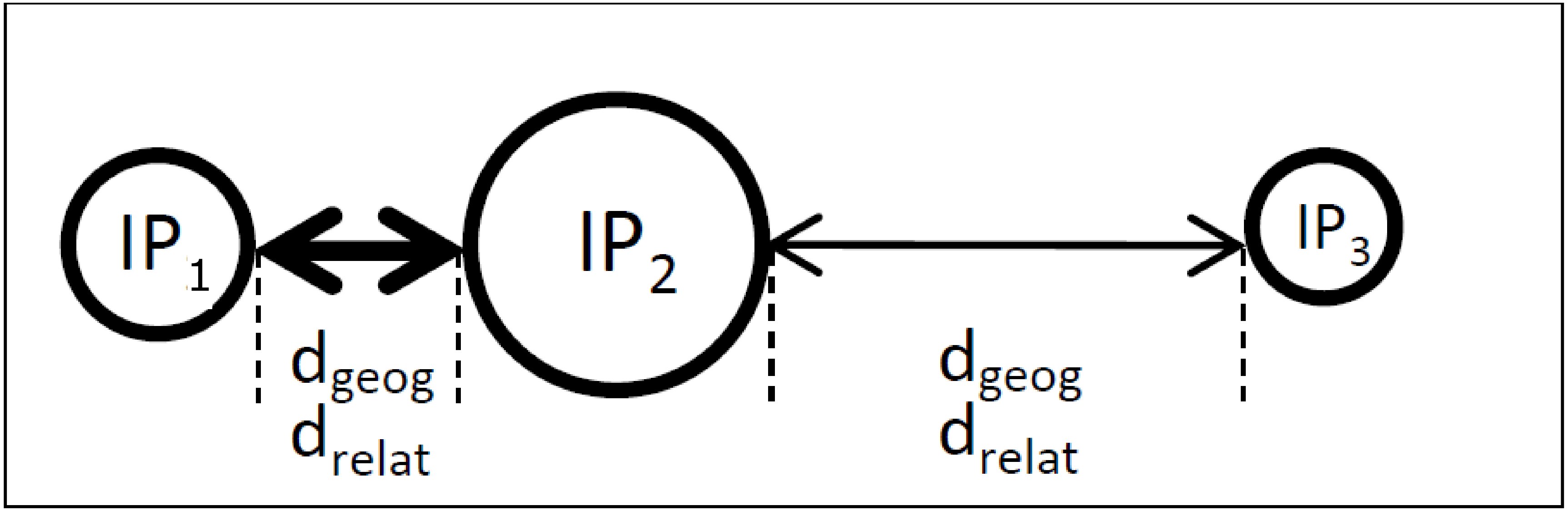


Figure 2: Conceptual model for understanding the different proximity impacts on CP

VI. Internet Infrastructure and Proximities

Different types of proximities

Proximity type	Variable	Data source	Expected sign
Geographic	Physical distance in km (natural logarithm)	Own calculations	-
Cognitive	Core-to-core (IP)	Own calculations	+
	Core-to-periphery (IP)	Own calculations	-
Organizational	World cities	GaWC, own calculations	+
Institutional	Intra-country virtual interaction	Own calculations	+
	Intra-region virtual interaction	Own calculations	+
Population	Absolute population distance (natural logarithm + 1)	Eurostat, Own calculations	?

VI. Internet Infrastructure and Proximities

Empirical testing of the impact of different types of proximities on the formation of CP

Gravity model to test the impact of physical distance and relational proximities on city-to-city IP communications links aggregated at NUTS3 city-region level.

$$\ln(IP_{ij,t}) = a_0 lnk + a_1 IP\_ln_{it} + a_2 IP\_ln_{jt} + a_3 t_2 + a_2 t_3 + a_5 t_4 + b_1 dist\_ln_{ij} + b_2 c2c_{ijt} + b_3 c2p_{ijt}$$
$$+ b_4 gawc_{ij} + b_5 cntr_{ij} + b_6 inter_{ij} + b_7 pop\_diff_{ijt} + b_7 \sum_{s=1}^{N} cntr_{ij}^{s} + \varepsilon_{ijt}.$$

$IP_{ij,t}$: the intensity of IP links between *i* and *j*

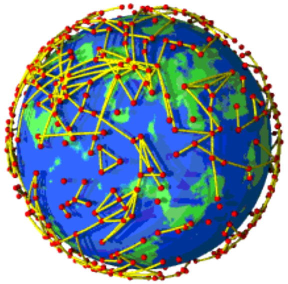
$IP_{i,t}$ and $IP_{j,t}$: mass of *i* and *j* (IP connectivity including extra-European links)

$b_{1\text{-}6}$: betas for the different proximity variables

year dummies, country-to-country effects

VII. Internet Infrastructure and Proximities: Results

Empirical testing of the impact of different types of proximities on the formation of CP



- Panel data specification: c. 40k city-to-city links for 4 years
- Random effects (RE)
- In order for the RE estimates to be consistent, there is a need for the unobserved random effects to be uncorrelated with the repressors
- The proximity variables might be endogenous by being correlated with omitted – unobservable – variables which affect the formation of IP links between regions
- Use of Hausman and Taylor (HT) model (Hausman and Taylor 1981). This model utilizes both the between and within variation of the exogenous variables as instruments ➔ Hausman test (Hausman 1978) in order to test the exogenous nature of the regressors
- Correction for potential selection bias

Dep. Var.: Ip_ln	(1)	(2)	(3)	(4)	(5)	(6)	(7)
dist_ln	-0.935	-0.92	-0.922	-0.352	-0.344	-0.34	-0.192
	(0.008)***	(0.008)***	(0.008)***	(0.009)***	(0.010)***	(0.011)***	(0.010)***
c2p		-0.178	-0.17	-0.116	-0.153	-0.064	-0.112
		(0.019)***	(0.019)***	(0.018)***	(0.019)***	(0.018)***	(0.018)***
c2c		0.555	0.538	0.36	0.368	0.387	0.243
		(0.030)***	(0.030)***	(0.030)***	(0.030)***	(0.030)***	(0.028)***
gawc			0.397	0.34	0.303	0.424	0.157
			(0.047)***	(0.043)***	(0.045)***	(0.044)***	(0.040)***
cntr				1.841	1.823	1.032	1.058
				(0.022)***	(0.023)***	(0.259)***	(0.242)***
inter				2.733	2.967	2.358	1.537
				(0.044)***	(0.053)***	(0.053)***	(0.049)***
pop_diff					0.043	-0.019	-0.05
					(0.006)***	(0.006)***	(0.006)***
ip_o_ln	0.445	0.477	0.468	0.572	0.571	0.636	0.473
	(0.005)***	(0.006)***	(0.006)***	(0.005)***	(0.006)***	(0.006)***	(0.006)***
ip_d_ln	0.392	0.421	0.415	0.569	0.568	0.635	0.473
	(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.006)***	(0.006)***	(0.006)***
							(0.015)***
Constant	1.477	0.894	1.007	-5.543	-5.76	-5.813	-5.272
	(0.062)***	(0.070)***	(0.072)***	(0.098)***	(0.102)***	(0.282)***	(0.263)***
Time effects	yes	Yes	yes	yes	yes	yes	yes
Country-pair effects	no	no	no	no	no	yes	yes
Hausman test	-	-	-	-	-	147.24	-
Observations	83700	83700	83700	83700	77553	77553	77553
Select.bias var.							yes
Number of link	44518	44518	44518	44518	42396	42396	42396

Note: Standard errors in parentheses.

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

VIII. Internet vs. Physical Geography: the Role of Distance

Results

IP connectivity appears to be ***higher*** between neighbouring regions in terms of:

- physical,
- technological,
- organizational, and
- institutional distance.

➔ Tobler’s first law of geography is valid in CP

➔ Border and localization effects become significant, even for the digital infrastructure

➔ Costs are also observed in terms of linking dissimilar agglomerations

IX. Concluding Remarks

- Centripetal forces agglomerate IP links in specific locations, which act as the hubs of this digital infrastructure (transaction costs)
- Centrifugal forces ‘protect’ the less-connected regions, securing a level of connectivity which would not be observed if clear SF structures were utilized
- Core-periphery patterns can be identified at a global level (centralisation benefits)
- Border and even local effects have a strong impact on IP connectivity reflecting both cost constraints but also prospects for demand for local communications

- Novelty of research: spatial and quantitative perspective on digital world
- New research questions emerge for virtual phenomena with real-world implications
- Gravity models are also valid in a digital world
- Lesson: great perspective for knowledge networks on trade


Thank You!