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Solving a Long Standing Debate on Optimal Network Embeddedness …?

Victor Gilsing

Department for Organisation Studies

& Centre for Innovation Research

Tilburg University

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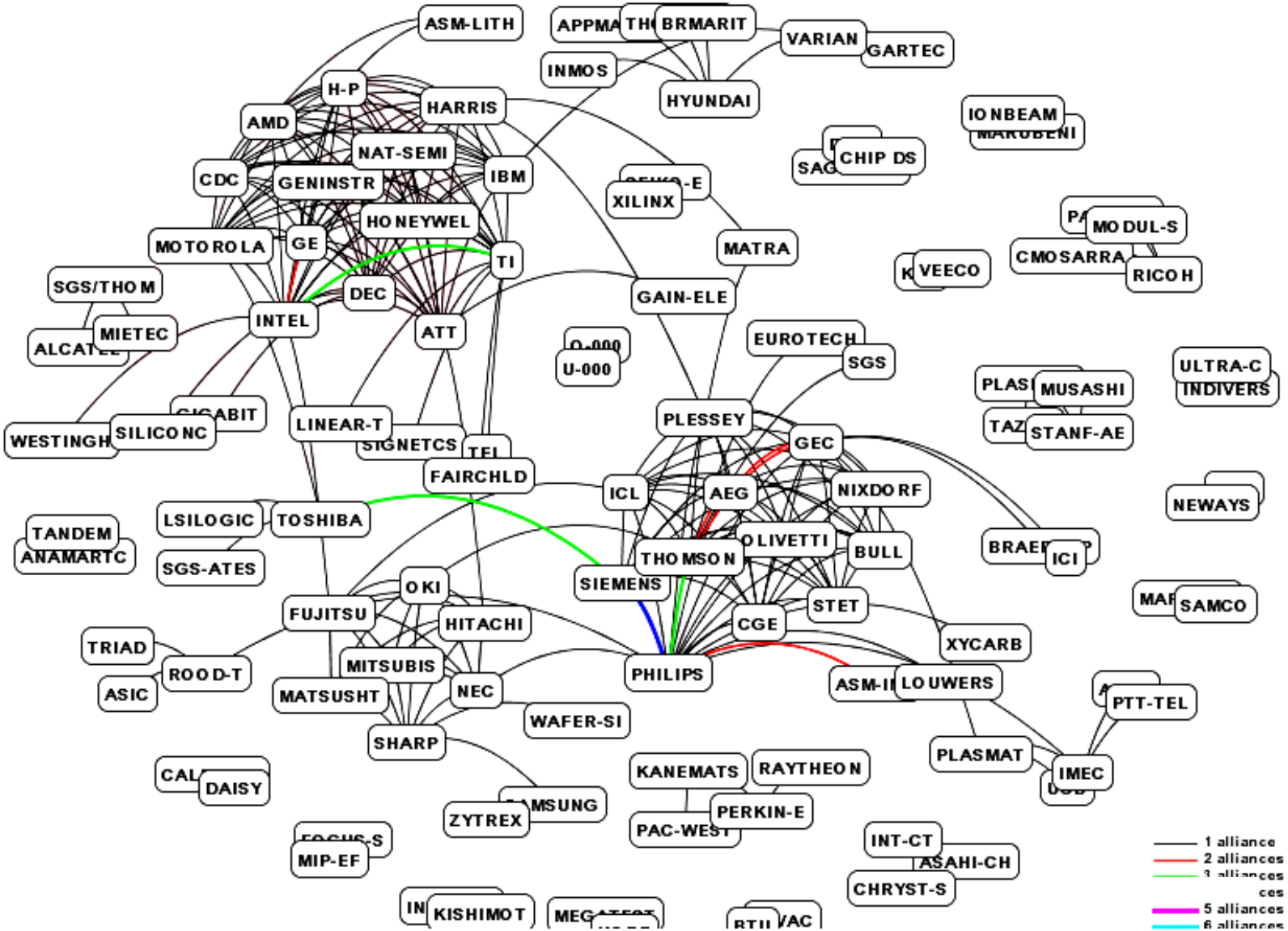
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RAYTHEON
DAISY
PERKIN-E
ZYTREX
PAC-WEST
INT-CT
ASAHI-CH
MIP-EF
CHRYST-S
KISHIMOT
1 alliance
2 alliances
5 alliances

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What explains alliance formation of firms?

- Exogenous drivers: why
  - – Resource complementarities
  - ➢ Incentives
- Endogenous drivers: how
  - – Position
  - – Pattern of prior relations
  - ➢ Opportunities

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What brings alliance formation to firms?

- Network embeddedness
  - Access to resources
  - Access to information
  - Control benefits (sanctions, reputation, trust)
- Positive effect on corporate performance
  - Growth (Powell et al., 1996)
  - Speed of innovation (Hagedoorn, 1993)
  - Organizational learning (Hamel, 1991)
  - Reputation (Stuart, 1998)

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What is an optimal network structure?

- Burt – structural hole argument (1992):
  Non- redundancy in view of efficiency

- Coleman (1988) – closure argument (1988):
  Redundancy in view of trust and sanctions

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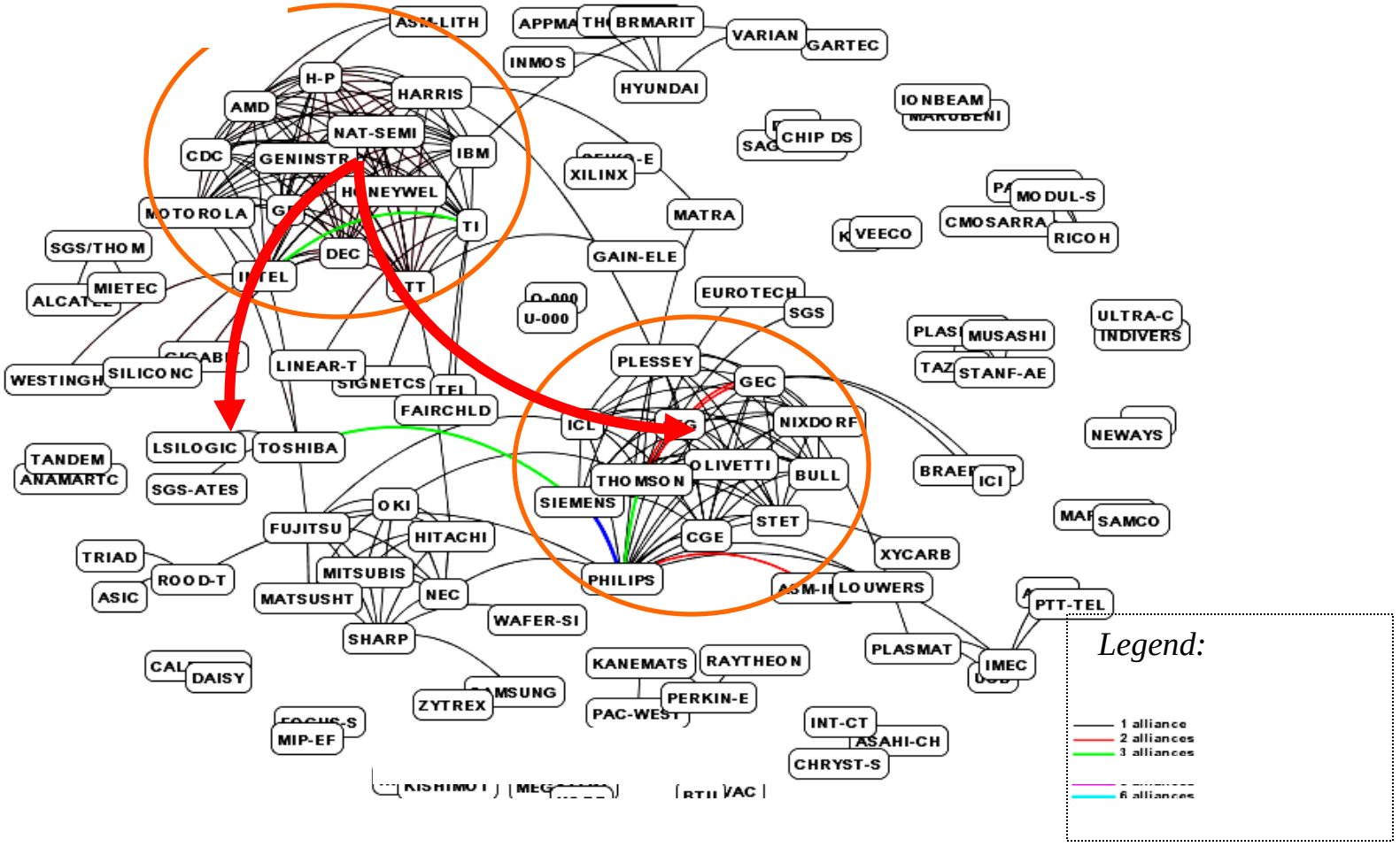

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What is an optimal network structure?

- Burt – structural hole argument (1992):
  Non- redundancy in view of efficiency
- Coleman (1988) – closure argument (1988):
  Redundancy in view of trust and sanctions
- Mixed empirical evidence

Can this debate be solved?

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Network embeddedness and the exploration of novel technologies: technological distance, betweenness centrality and density

(Forthcoming in *Research Policy*)

Victor Gilsing
Bart Nooteboom
Wim van Haverbeke
Geert Duysters
Ad van den Oord

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Key claim

Burt versus Coleman:

Not *competing* views

….but…

complementary views

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Key claim

Burt versus Coleman:

Within a context of Technological Innovation

But with implications (far) beyond this

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Optimal network embeddedness for exploration of novel technology

3 dimensions of network embeddedness:

- Technological distance
- Firm's network position
- Total network density

"Cognitive view"

"Social structural view "

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Theory and Hypotheses

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Exploration vs. Exploitation
(March, 1991)

- Exploitation
  - Local search (Nelson & Winter, 1982)
  - Core technology
  - High chance of immediate and positive returns
  - However: risk of obsolescence and lock-out from new developments

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Exploration vs. Exploitation
(March, 1991)

- Exploitation
- Exploration
  - Distant search
  - Non-core technology
  - Uncertain returns: remote in time and place
  - However: “it is only way to finish first”

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Role of Technological Distance

Technological distance

= lack of overlap in technological knowledge

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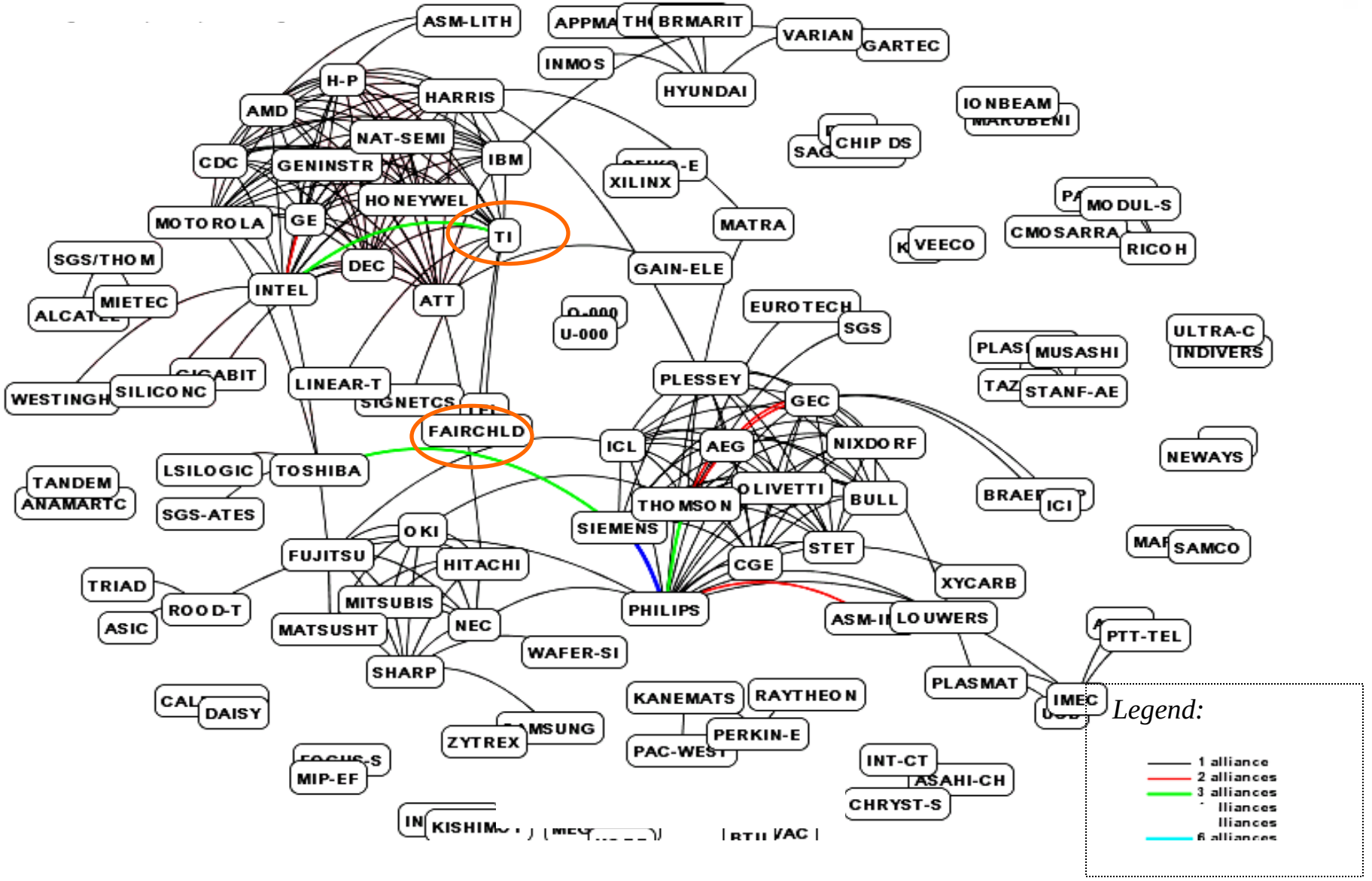

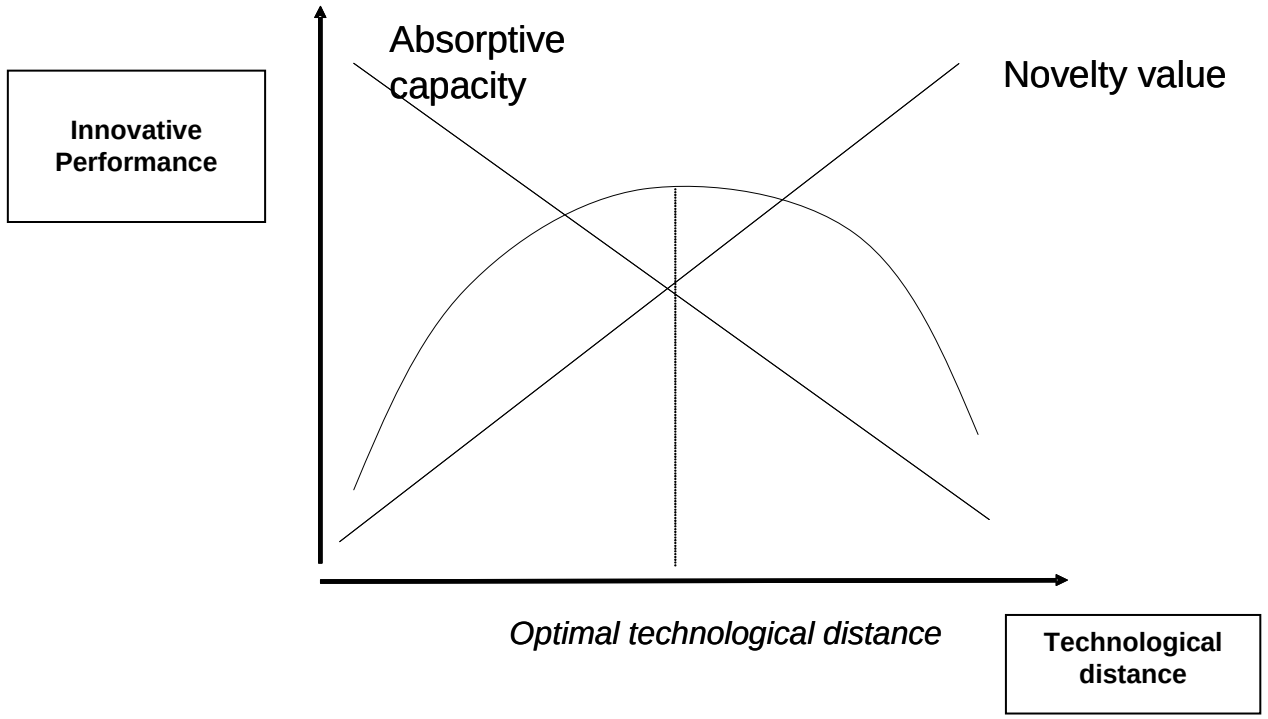

Figure 1: Novelty and absorptive capacity (Nooteboom et al., 2007)

$$AC = a_0 - a_1 \cdot TD(a_0, a_1 > 0), \quad (1)$$

and

$$NV = b_0 + b_1 \cdot TD(b_0, b_1 > 0). \quad (2)$$

where AC is the absorptive capacity, NV is the novelty value and TD is the technological distance.

The innovation performance of collaboration in the dyad (=IP) is defined as the product of the two linear effects:

$$IP = AC \cdot NV \quad (3)$$

Replacing AC and NV by the right-hand side of Eqs. (1) and (2) yields:

$$IP = a_0 \cdot b_0 + (a_0 \cdot b_1 - b_0 \cdot a_1)TD - a_1 \cdot b_1 \cdot TD^2 \quad (4)$$

Eq. (4) results in an inverse U-shaped effect if and only if:

$$a_0 \cdot b_1 > b_0 \cdot a_1 \quad (5)$$

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Role of Technological Distance

Technological distance

= lack of overlap in technological technology knowledge

Little distance: no potential for learning (no novelty value)

Large distance: no potential for learning (no understanding)

THEREFORE:

- Need sufficient technological distance to create something new,
- but not too much…otherwise no mutual understanding

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Hypothesis 1:

Exploration of novel technology is an inverse U-shaped function of technological distance

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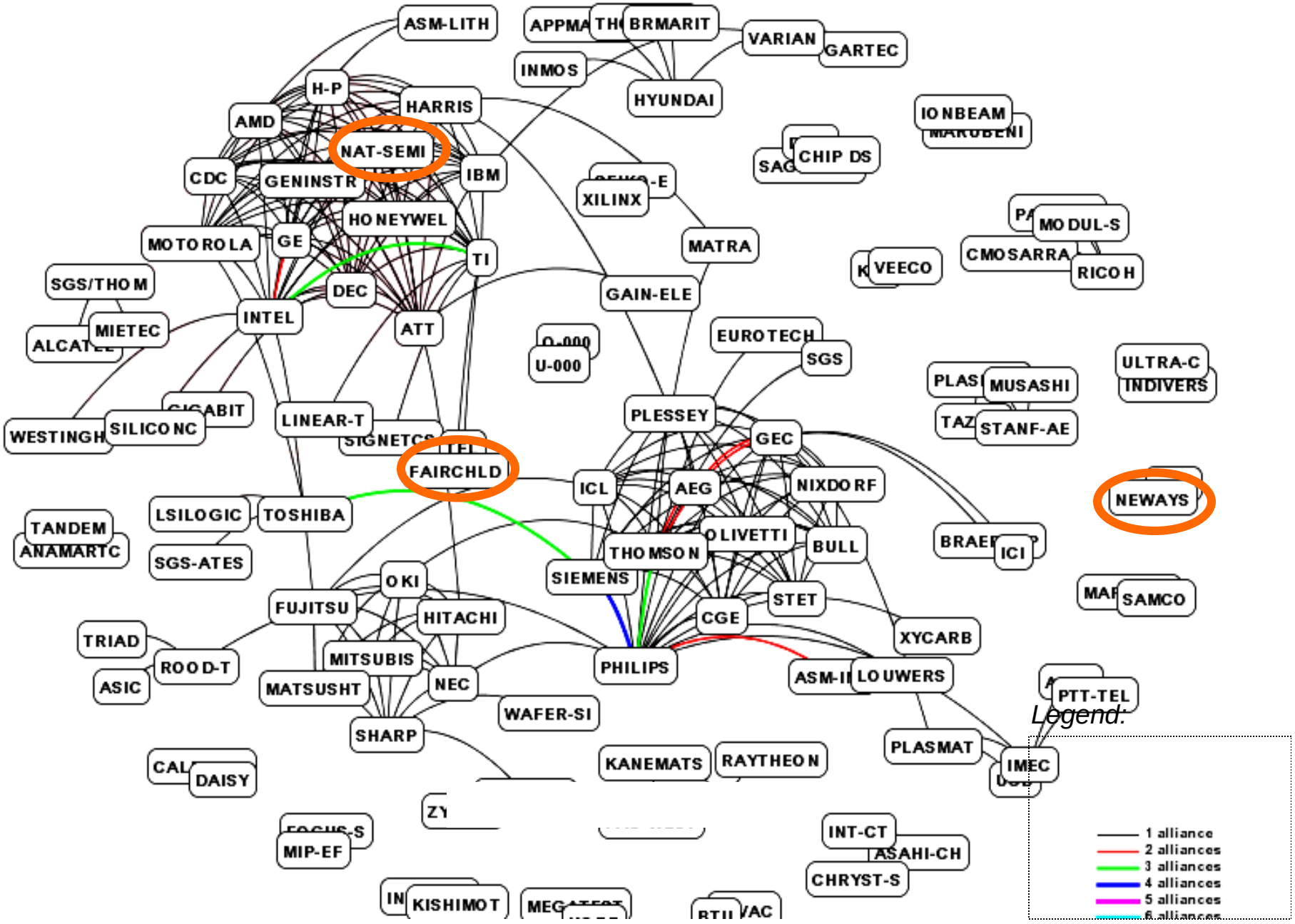
Role of Network Position
- Burt's view -

otential for novelty value larger across groups than within groups

Structural holes (cf. Burt, 1992)

High centrality: brokerage between groups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MIP-EF
CHRYST-S
KISHIMOT
Legend:
1 alliance
2 alliances
3 alliances
4 alliances
5 alliances

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Role of Network Position

entral firms:

- are better informed

    - are more attractive partners

o, central positions bring you:

- access to novel knowledge at larger technological distance

owever, central positions also create:

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Role of Network Position

eripheral position: no potential for learning (no novelty value)

ighly central position: no potential for learning (no understanding)

HEREFORE:

- Being central is attractive….

- …but not *too* much….

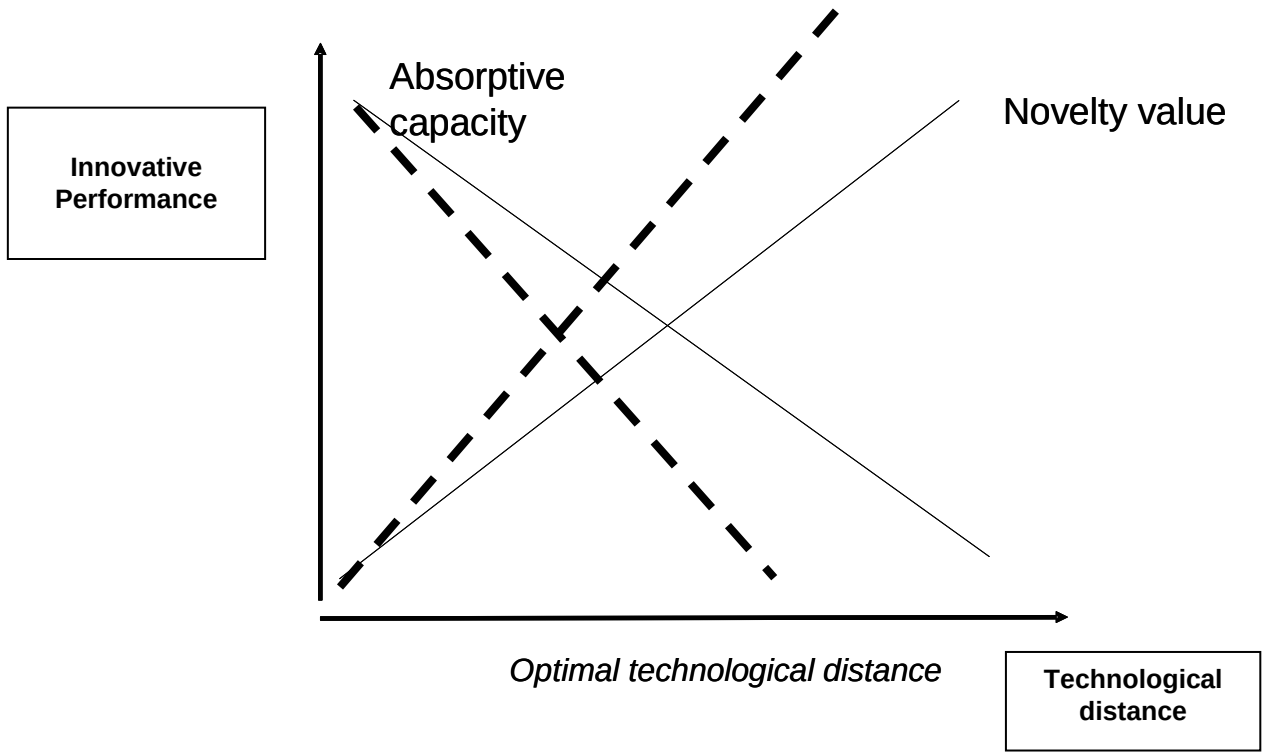

Figure 1: Novelty and absorptive capacity (Nooteboom et al., 2007)

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Hypothesis 2 :

Exploration of novel technology is an inverse U-shaped function of network centrality

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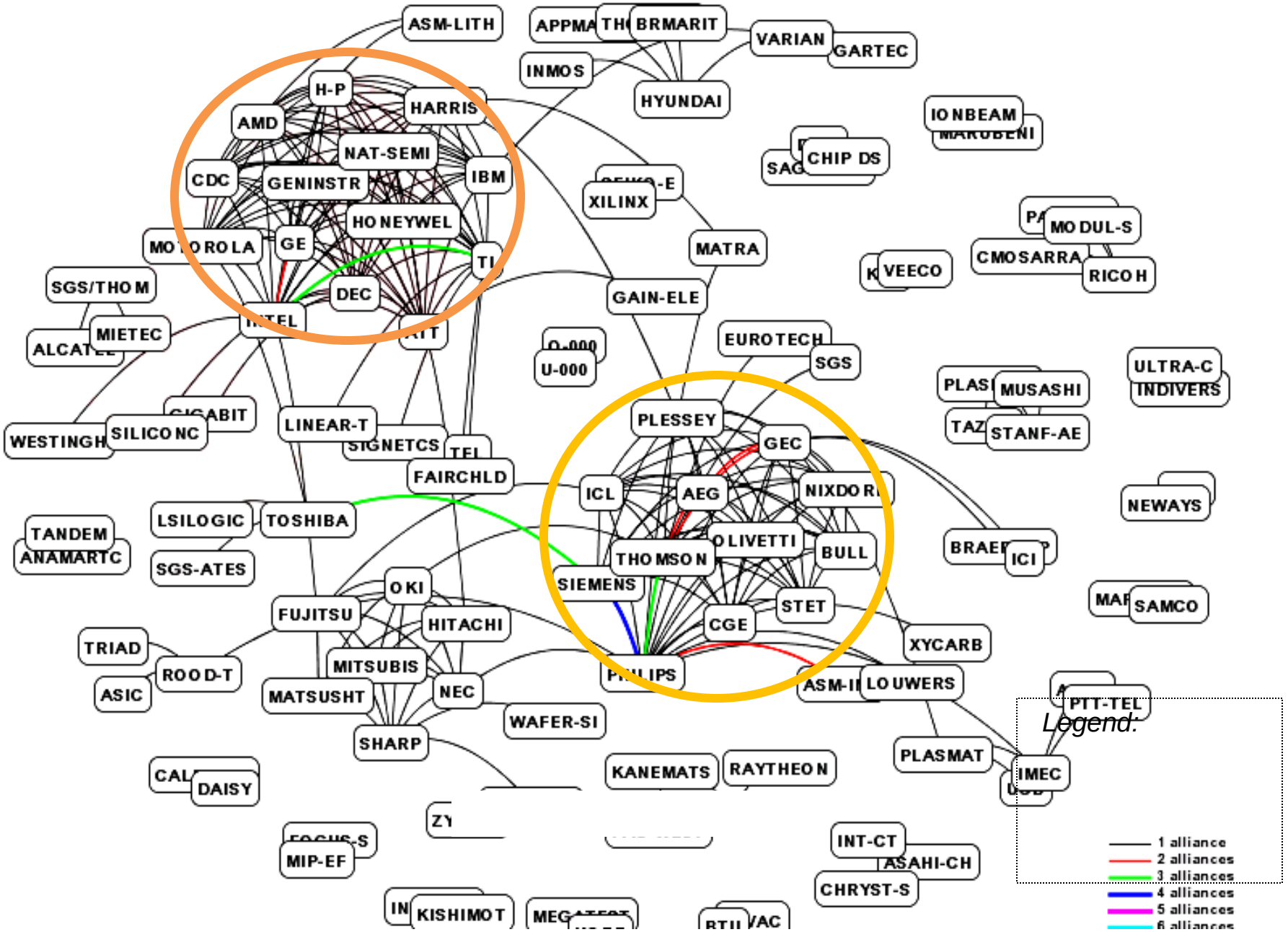
Role of Network Density
- Coleman's view -

Closure provides *social capital*

Closure of the social structure is important for the existence of *effective norms*

Closure creates *trust* in a social structure

Closure creates *secure information flows*.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PTT-TEL
WAFER-SI
SHARP
PLASMAT
IMEC
CAL
DAISY
KANEMATS
RAYTHEON
ZY
FOCUS-S
MIP-EF
INT-CT
ASAHI-CH
CHRYST-S
IN
KISHIMOT
MEG
RTI
VAC
Legend:
1 alliance
2 alliances
3 alliances
4 alliances
5 alliances
6 alliances

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Role of Network Density

Argument in favor of dense networks

- Network enhances build up of absorptive capacity

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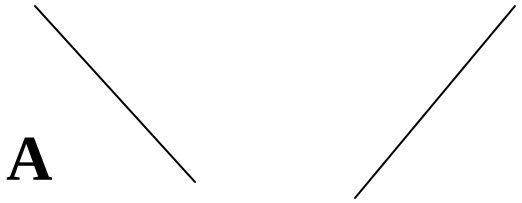
Role of Network Density

ven if direct ties are redundant for access to information, both may be needed to understand and absorb knowledge in the relationship



A linked to **B** and **C** despite link between **B** and **C**
This may help **A** understand **B** by comparing him to **C**

n addition: dense networks facilitate build-up of trust

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Role of Network Density

Arguments against dense networks

1. Costs establishing + maintaining contacts

2. ‘Everyone knows what everyone knows’
   - Limited potential for novelty creation

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Role of Network Density

In sum, dense networks:

- Supports build up of absorptive capacity, but,…

- May impede novelty creation

THEREFORE:

- *Some* density is good….
- …but not too much….

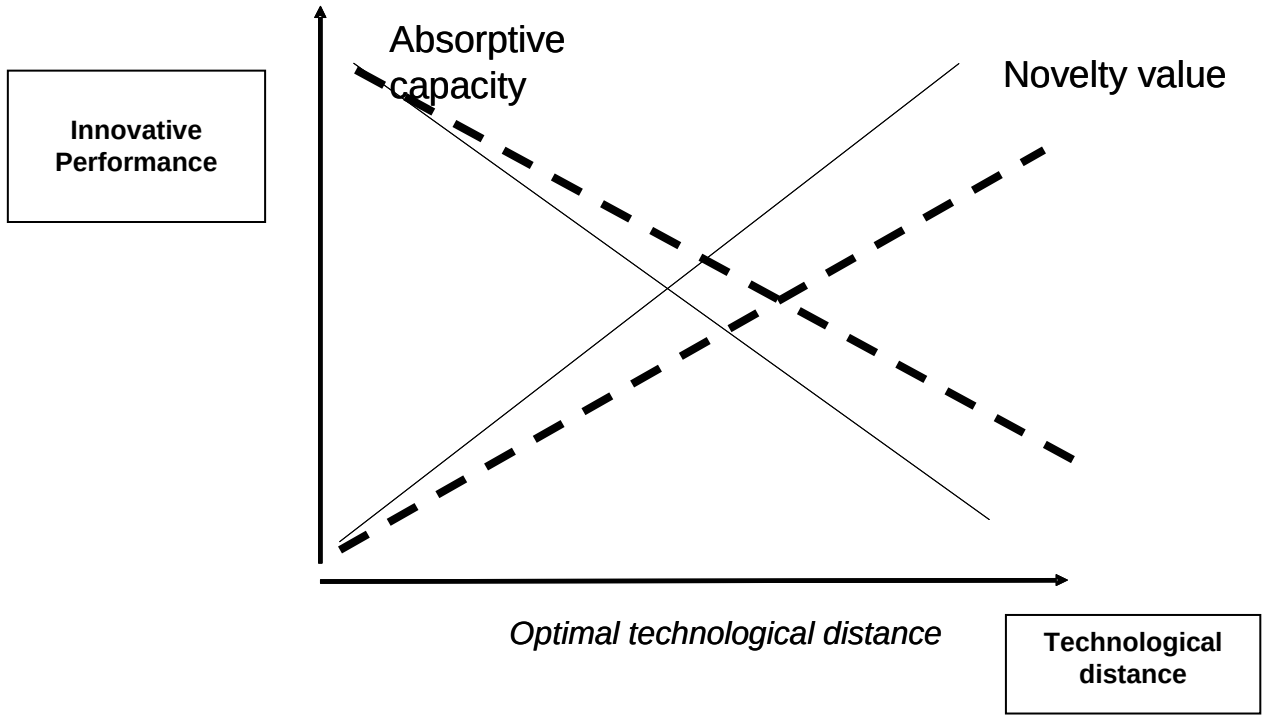

Figure 1: Novelty and absorptive capacity (Nooteboom et al., 2007)

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Hypothesis 3:

Exploration of novel technology is an inversed U-shaped function of density

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Combined Effects

$$AC = a_0 - a_1 \cdot TD - a_2 \cdot BC + a_3 \cdot D \tag{6}$$

$$NV = b_0 + b_1 \cdot TD + b_2 \cdot BC - b_3 \cdot D,$$

$$a_0, a_1, a_2, a_3, b_0, b_1, b_2, b_3 > 0 \tag{7}$$

Multiplying (6) and (7) provides the equation for exploration performance (IP):

$$\begin{aligned} IP = AC \cdot NV = {} & (a_0 \cdot b_1 - b_0 \cdot a_1) \cdot TD + (a_0 \cdot b_2 - b_0 \cdot a_2) \\ & \cdot BC + (b_0 \cdot a_3 - a_0 \cdot b_3) \cdot D - a_1 \cdot b_1 \cdot TD^2 \\ & - a_2 \cdot b_2 \cdot BC^2 - a_3 \cdot b_3 \cdot D^2 - (a_1 \cdot b_2 + a_2 \cdot b_1) \\ & \cdot TD \cdot BC + (a_1 \cdot b_3 + a_3 \cdot b_1) \cdot TD \cdot D \\ & + (a_2 \cdot b_3 + a_3 \cdot b_2) \cdot BC \cdot D \end{aligned} \tag{8}$$

where

$$a_0 \cdot b_1 > b_0 \cdot a_1, a_0 \cdot b_2 > b_0 \cdot a_2 \quad \text{and} \quad b_0 \cdot a_3 > a_0 \cdot b_3$$

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Combined Effects

Hypothesis 4:

The interaction between technological distance and betweenness centrality has a negative effect on exploration

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Combined Effects

Hypothesis 4:

The interaction between technological distance and betweenness centrality has a negative effect on exploration

Hypothesis 5:

The interaction between technological distance and density has a positive effect on exploration

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Hypothesis 6:

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Combined Effects

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Hypothesis 6:

The interaction between betweenness centrality and density has a positive effect on exploration

→ ***Indicative of complementary views***

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Model Specification and Estimation

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Empirical setting

Three industries:

- Pharmaceuticals, Automotives, Chemicals
- Similarities
- Differences
- Unbalanced panel
  - 116 firms and 1137 observations
  - 12 year period: 1986-1997
  - MERIT-CATI

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Model specification
- dependent variables-

- Exploration = new to the firm
  - # patents filed for in a particular year in patent classes (2 digit: 400 classes)
  - None in previous 5 years
  - Explorative nature of a patent holds for 3 (or 5) consecutive years
  - Akin to ‘novel technologies’ = ‘new-to-the-firm’ (cf. Ahuja and Lampert, 2001)

p.m. technological profiles

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Model specification
- *independent variables*-

- **Technological distance**
  - CTRA (Pearson's correlation)
    - index of distribution across technological classes of the revealed technological advantages (RTA) of each firm relative to the other sample firms

  - Positive status = similarity of pattern of technological specialization of firms (i.e. lack of distance)
  - Transformation:
    - low value = low distance
    - high value = large distance

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Model specification
- *independent variables*-

- **Technological distance**

- **Overall network density**

$$= \frac{\text{\# of all ties in the network}}{\text{total \# of possible ties}}$$

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Model specification
- *independent variables*-

- **Technological distance**
- **Overall network density**
- **Network centrality**

  = Betweenness centrality: centrality of the focal firm in the network = shortest geodesic path

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Controls and Econometric Issues

- **Controls**
  - Firm-based
    - Age
    - Size
    - R&D intensity
  - Other
    - Location (Asia, Europe, US)
    - Time
    - Industry

- **Control for unobserved heterogeneity**
  - Inclusion of lagged DV

- **Standardisation of variables before interacting them (MC)**

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Estimation Results

Table 3: Determinants of the patent rate of firms in explorative patent classes 1986-1997

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Explanatory variables						
Technological distance		0.0631**			0.0441**	0.0634**
		(0.0282)			(0.0208)	(0.0291)
(Technological distance)^2		-0.0634**			-0.0537***	-0.0412***
		(0.0147)			(0.0152)	(0.0156)
Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828***
						(0.0282)
(Technological distance) * (density)						0.0293
						(0.0191)
(Betweeness centrality) * (density)						0.0299**
						(0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***0.9572***	0.9773***	
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

H1

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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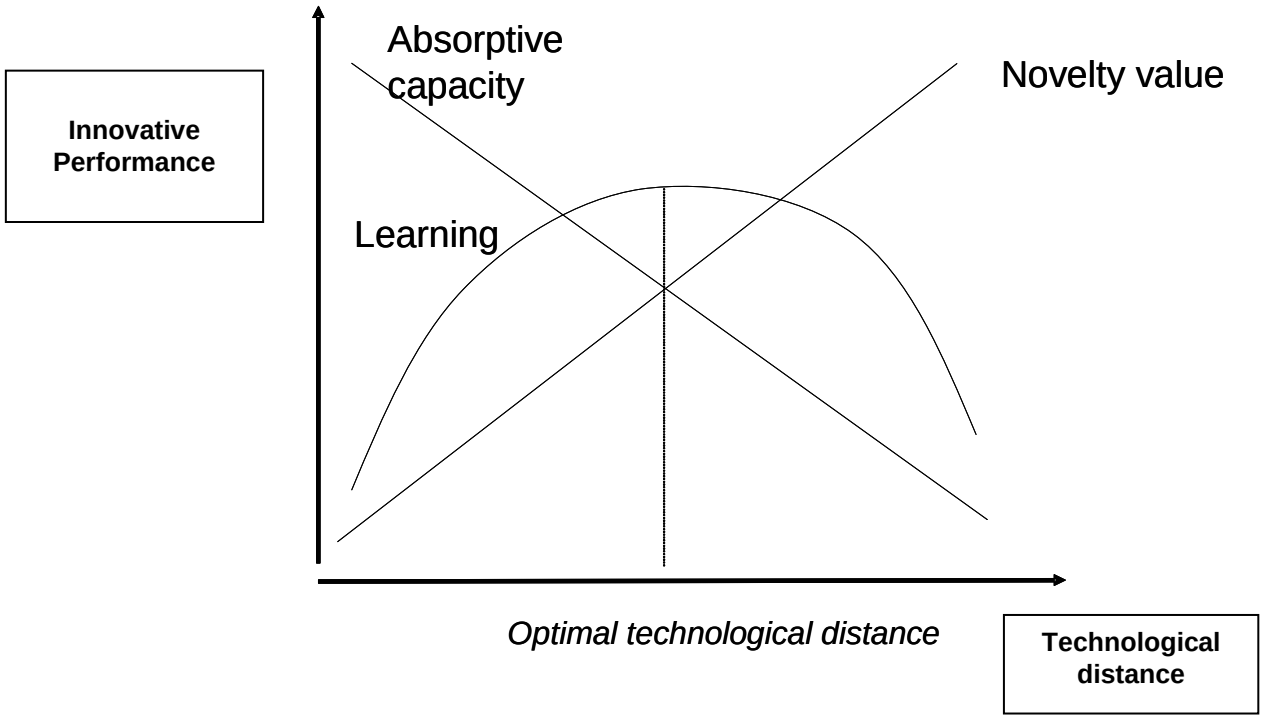
Hypothesis 1



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Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828***
						(0.0282)
(Technological distance) * (density)						0.0293
						(0.0191)
(Betweeness centrality) * (density)						0.0299**
						(0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***0.9572***	0.9773***	
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

H2

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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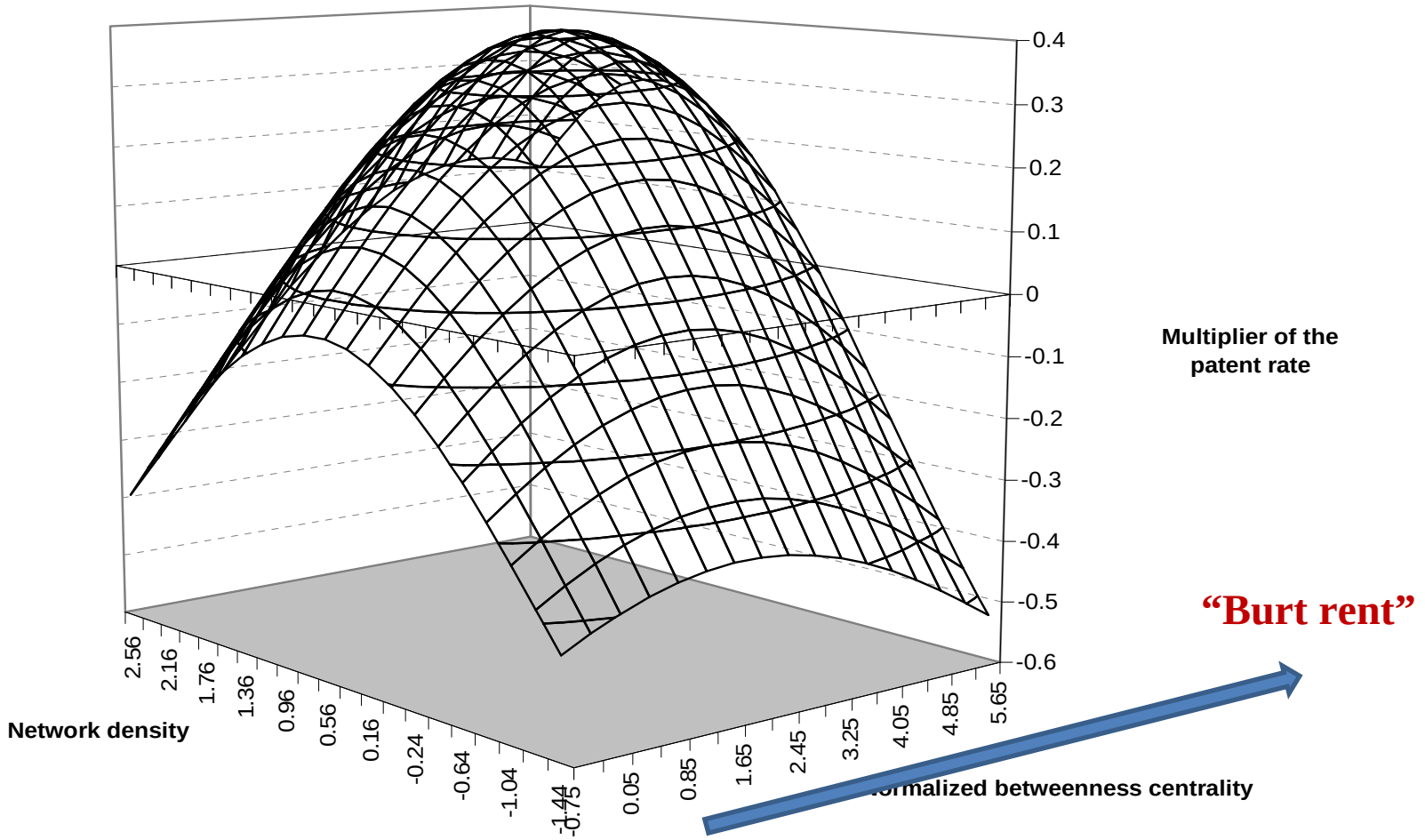

Hypothesis 2

Table 3: Determinants of the patent rate of firms in explorative patent classes 1986-1997

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Explanatory variables						
Technological distance		0.0631**			0.0441**	0.0634**
		(0.0282)			(0.0208)	(0.0291)
(Technological distance)^2		-0.0634**			-0.0537***	-0.0412***
		(0.0147)			(0.0152)	(0.0156)
Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828***
						(0.0282)
(Technological distance) * (density)						0.0293
						(0.0191)
(Betweeness centrality) * (density)						0.0299**
						(0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***	0.9572***	0.9773***
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

H3

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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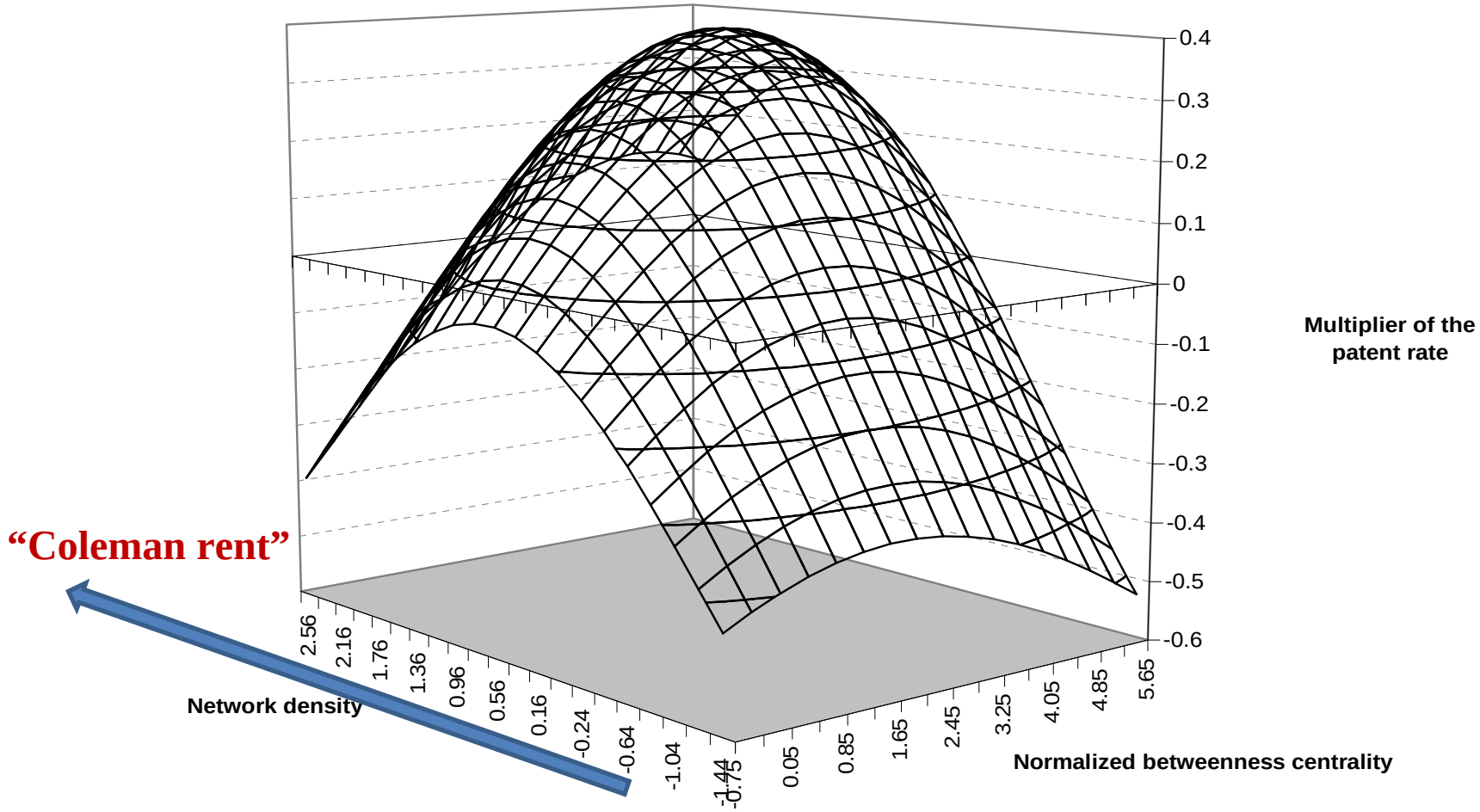

Hypothesis 3

Table 3: Determinants of the patent rate of firms in explorative patent classes 1986-1997

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Explanatory variables						
Technological distance		0.0631**			0.0441**	0.0634**
		(0.0282)			(0.0208)	(0.0291)
(Technological distance)^2		-0.0634**			-0.0537***	-0.0412***
		(0.0147)			(0.0152)	(0.0156)
Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828***
						(0.0282)
(Technological distance) * (density)						0.0293
						(0.0191)
(Betweeness centrality) * (density)						0.0299**
						(0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***0.9572***	0.9773***	
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

H4

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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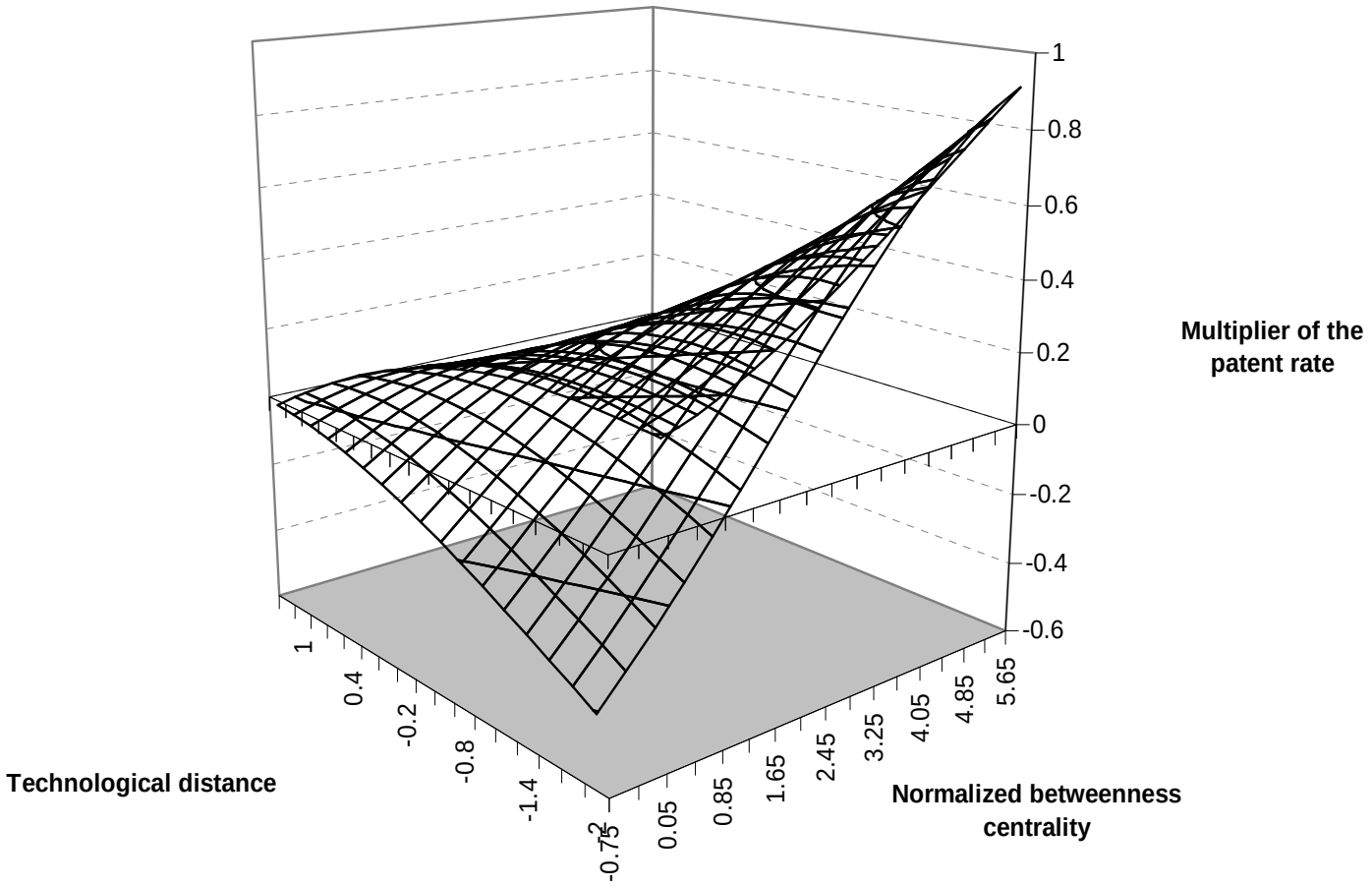

Hypothesis 4

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Table 3: Determinants of the patent rate of firms in explorative patent classes 1986-1997

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Explanatory variables						
Technological distance		0.0631**			0.0441**	0.0634**
		(0.0282)			(0.0208)	(0.0291)
(Technological distance)^2		-0.0634**			-0.0537***	-0.0412***
		(0.0147)			(0.0152)	(0.0156)
Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828*** (0.0282)
(Technological distance) * (density)						0.0293 (0.0191)
(Betweeness centrality) * (density)						0.0299** (0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***0.9572***	0.9773***	
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

H5 ?

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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Table 3: Determinants of the patent rate of firms in explorative patent classes 1986-1997

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Explanatory variables						
Technological distance		0.0631**			0.0441**	0.0634**
		(0.0282)			(0.0208)	(0.0291)
(Technological distance)^2		-0.0634**			-0.0537***	-0.0412***
		(0.0147)			(0.0152)	(0.0156)
Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828***
						(0.0282)
(Technological distance) * (density)						0.0293
						(0.0191)
(Betweeness centrality) * (density)						0.0299**
						(0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***0.9572***	0.9773***	
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

H6

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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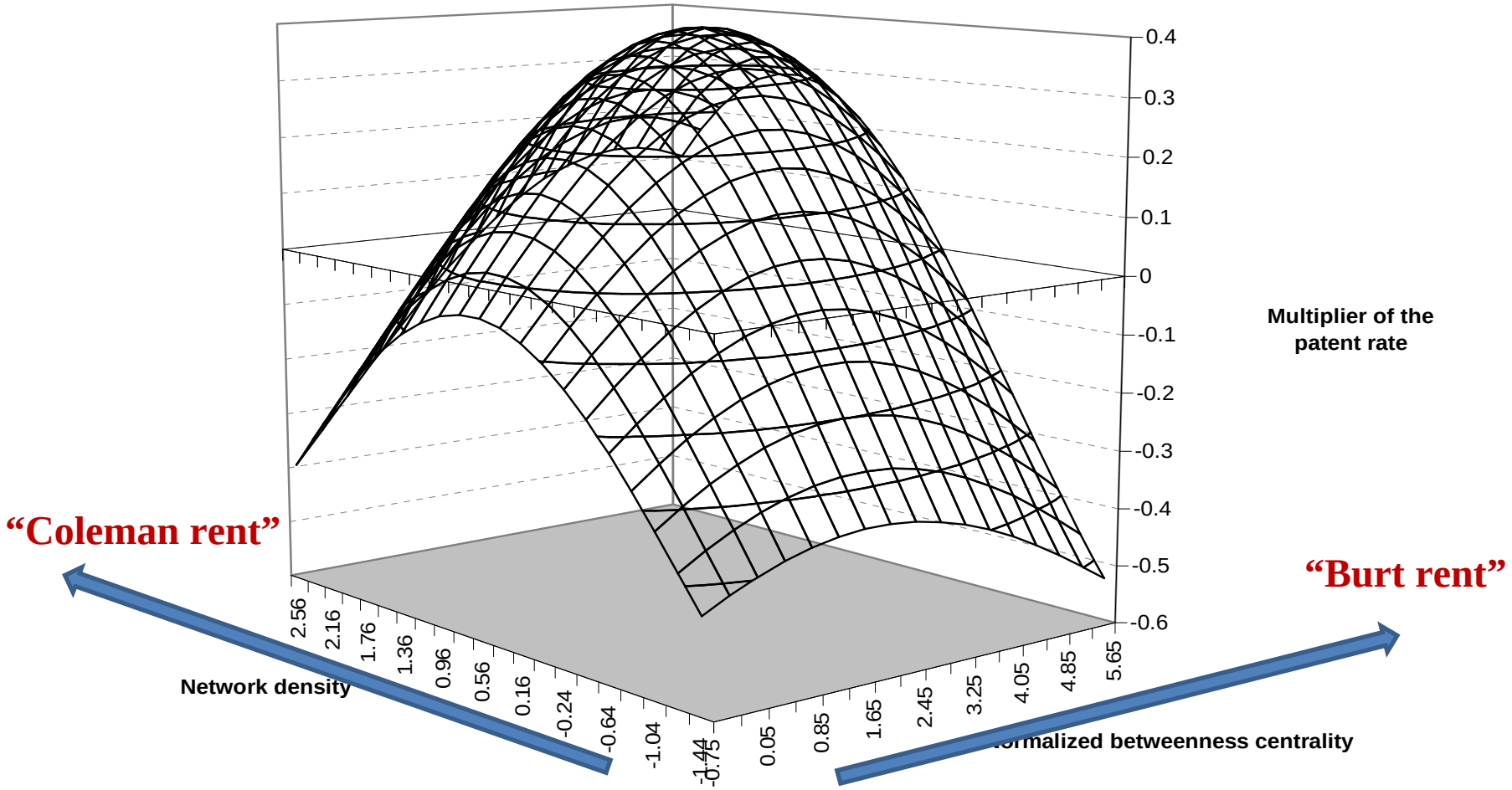

Hypothesis 6

Table 3: Determinants of the patent rate of firms in explorative patent classes 1986-1997

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Explanatory variables						
Technological distance		0.0631**			0.0441**	0.0634**
		(0.0282)			(0.0208)	(0.0291)
(Technological distance)^2		-0.0634**			-0.0537***	-0.0412***
		(0.0147)			(0.0152)	(0.0156)
Network density			0.1671***		0.1877***	0.1791***
			(0.0308)		(0.0328)	(0.0331)
(Network density)^2			-0.1028***		-0.1087***	-0.1208***
			(0.0132)		(0.0134)	(0.0142)
Betweeness centrality				0.1258***	0.1160***	0.1209***
				(0.0312)	(0.0376)	(0.0329)
(Betweenness centrallity)^2				-0.0119*	-0.0158**	-0.0214**
				(0.0070)	(0.0074)	(0.0086)
(Technological distance) * (betweeness centrality)						-0.0828***
						(0.0282)
(Technological distance) * (density)						0.0293
						(0.0191)
(Betweeness centrality) * (density)						0.0299**
						(0.0128)
Control variables						
Firm size (ln sales)	0.4351***	0.4269***	0.4036***	0.4113***	0.3745***	0.3676***
	(0.0459)	(0.0460)	(0.0459)	(0.0458)	(0.0462)	(0.0465)
R&D-intensity	1.1634***	1.1325***	1.0815***	1.0779***	0.9860***	0.9430***
	(0.2452)	(0.2452)	(0.2467)	(0.2489)	(0.2472)	(0.2486)
Age	-0.0014	-0.0015	-0.0020	-0.0015	-0.0021	-0.0027
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)
Car manufacturer	-0.8821***	-0.8841***	-0.9476***	-0.8271***	-0.9402***	-0.9208***
Chemical industry	-0.5303**	-0.5570**	-0.5387**	-0.4364*	-0.4907*	-0.5205*
	(0.2705)	(0.2698)	(0.2700)	(0.2648)	(0.2665)	(0.2680)
Europe	0.4352	0.3836	0.3946	0.3066	0.2318	0.2865
	(0.2891)	(0.2874)	(0.2887)	(0.2812)	(0.2826)	(0.2856)
Asia	0.0698	0.0185	0.0878	0.0355	0.0137	0.0711
	(0.2658)	(0.2652)	(0.2671)	(0.2588)	(0.2617)	(0.2651)
Year dummy variables [A]	Included	Included	Included	Included	Included	Included
Constant	-1.4792***	-1.321***	-0.8121	-1.2808**	-0.4438	-0.3302
	(0.5025)	(0.5043)	(0.5131)	(0.4959)	(0.5145)	(0.5200)
alpha 0.9890***[B]	0.9935***	0.9989***		0.9359***0.9572***	0.9773***	
	(0.1457)	(0.1445)	(0.1445)	(0.1389)	(0.1403)	(0.1431)
Number of firms	85	85	85	85	85	85
Number of firms-years	762	762	762	762	762	762
Log-Likelihood	-3009.4	-2989.0	-2979.0	-2998.3	-2959.4	-2951.6
Likelihood ratio test (df)[C]		40.8***	60.8***	22.2***	100.0***	15.6***
Df.			(2)	(2)	(2)	(6)

Size

Notes: Standard error between brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

A: Year dummy variables are included in the regressions but the coefficients and standard errors are not reported in the table.

B: Likelihood-ratio test of alpha = 0

C. Likeikood ratio test: Model 2-5 vs. model 1 and model 6 vs. model 5

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Discussion and conclusions

What have we learned?

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Key Conclusions

Aim of the study: analyze a firm's network embeddedness for exploration of novel technology

Role of network embeddedness to increase success of exploration of novel technology – dual emphasis:

- Central position for novelty value
- Network density for understanding and absorptive capacity

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Key Conclusions

Burt versus Coleman: not competing but *complementary* views

Balancing Act (1)

Create access to heterogeneity

…but also…

Create adequate level of density

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Key Conclusions

However, complementarity Burt versus Coleman up to a point

Balancing Act (2)

Create access to heterogeneity *but not too much…*

…as well as …

Create adequate level of density *but not too much*

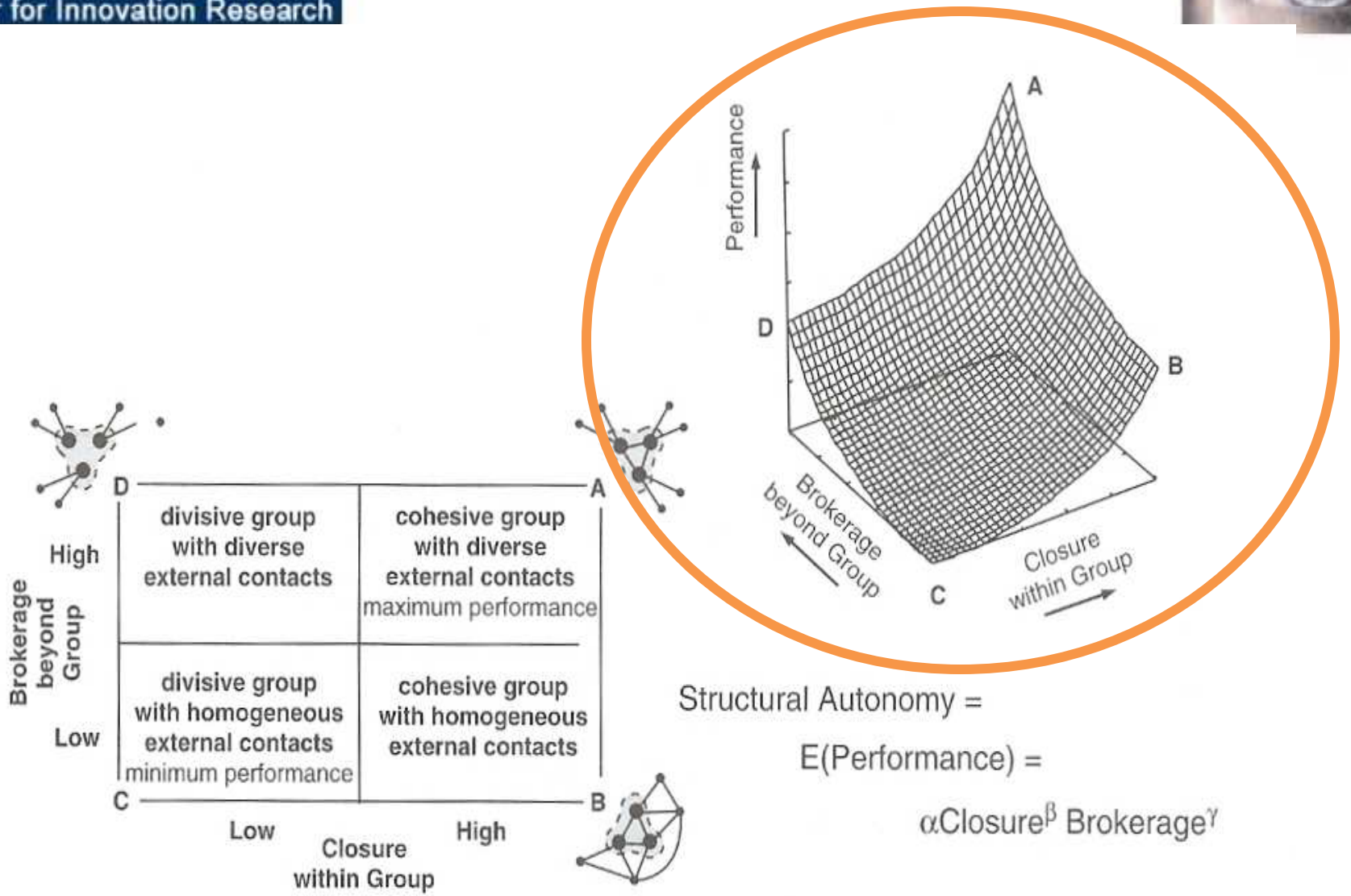

Fig. 3.5: Performance is highest for closure within a group combined with brokerage beyond the group (stylized fact #3)

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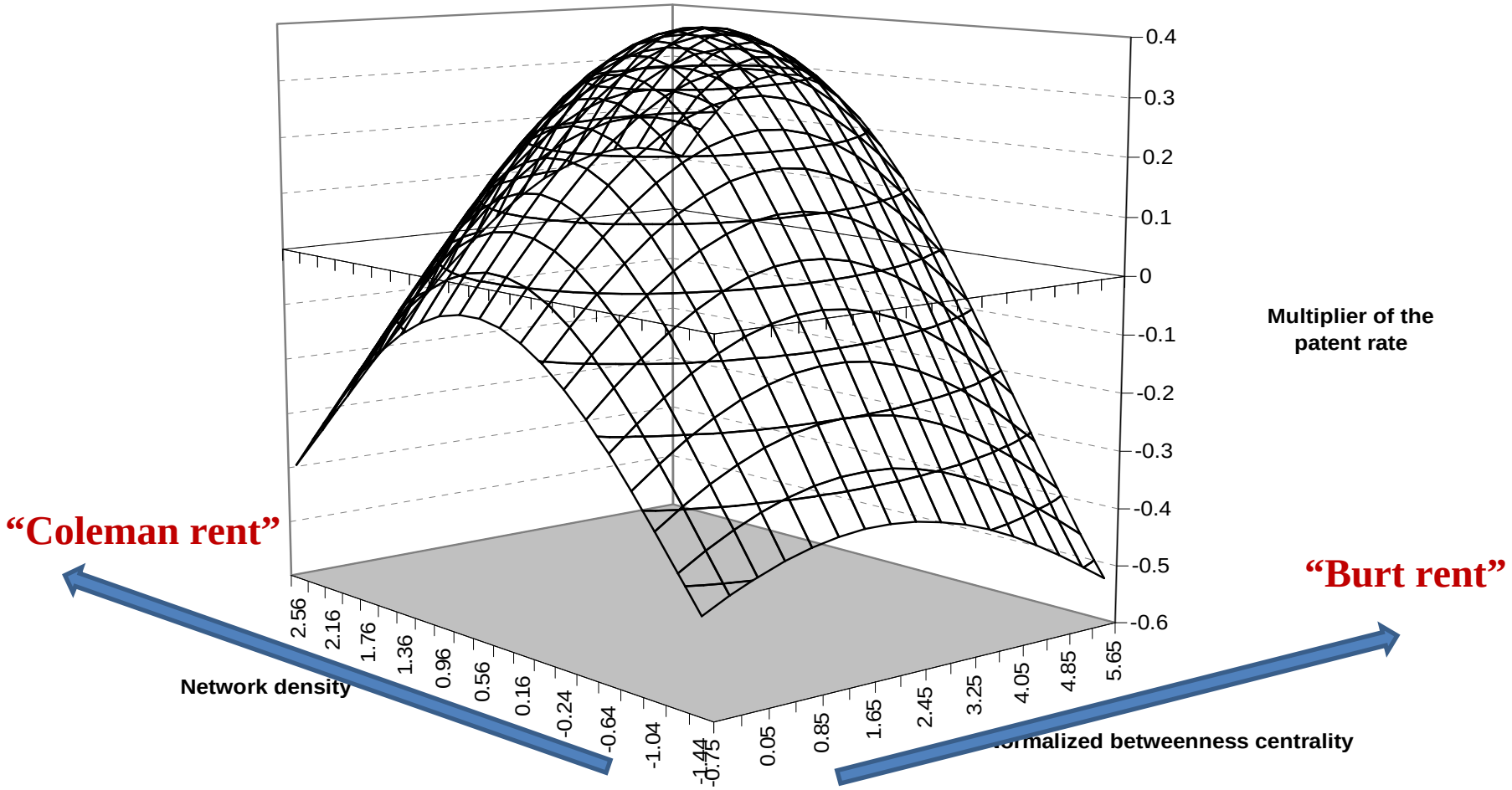

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Thank you!