Assessing Complementarity Effects of Intangible Capital

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Agenda

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Complementarity

"Complementarity involves the interactions among changes in different variables."

"[It] gives rise to system effects, with the whole being more than the sum of the parts."

"When choice variables are complementary, any environmental change that increases the attractiveness of raising one of the variables tends to result in all of them being increased. This gives rise to systematic, predictable patterns in how the choices move in response to environmental changes."

[Roberts, J., 2008]

Part I
Defining IC Indices to Compare Creative Cities

Background

Why we need indices

We need to somehow elucidate performance of the complex systems which define creative cities.

- Benchmark.
- Foster creative imitation of effective policies.

Criticism

> *"[T]hose constructing suitable indices are confronted with a number of key challenges not least of these being what variables to include and how to aggregate them into a composite index for ranking purposes."*
>
> *"[I]ndices perform poorly as a policy-making tool in terms of their ability to predict and rank national economic performance."*
>
> [Berger, T. and Bristow, G., 2009]

Quantitative Approach

1. *Principal-component Factor Analysis* identifies factors which represent the common variance in the data.
   - 1.1 We classify variables in factors (groups) of common correlations. We then interpret these factors based on their key variables.
   - 1.2 We create associated indices (factor scores) for each city based upon the resulting structure of factors.
     - The weight of a variable in the index is determined by the correlation with the factor.

2. We proceed to define econometric models which include these indices as independent variables and GDP per capita as the dependent variable. We use regressions to check the pertinence of each index in terms of economic output.

3. We then rank cities using the significant portion from the dataset, i.e., employing the index/indices with a significant statistical correlation with GDP per capita.

[Eurostat + OECD] — Dataset A

Sources

- (32) Indicators [2003-2010]:
  Eurostat (Urban Audit & Regional Statistics)
  - (8) Science, Technology and Education
  - (9) Economic Variables
  - (7) Environment/Health and Culture
  - (7) Demographics
- (3) Output and Control Variables [2005]:
  OECD (Competitive Cities in the Global Economy)

20 Cities

1. Barcelona
2. Berlin
3. Budapest
4. Copenhagen
5. Frankfurt
6. Hamburg
7. Helsinki
8. Lille
9. Lisbon
10. London
11. Lyon
12. Madrid
13. Milan
14. Munich
15. Paris
16. Rome
17. Stockholm
18. Turin
19. Valencia
20. Vienna

[Eurostat + OECD] — Factor Analysis

	F1	F2	F3	F4	F5
patents		X	X		
hpatent		X			
gerd		X			
patentsict		X			
researchers	X				
hrst	X				
students				X	
qual		X			
empcom			X		
empfinan			X		
empindce	X				
empindgp	X		X		
empthr	X				
empself	X				
ictmanu		X			X
ictserv	X				
ictcont	X		X		
ozone	X				
hospital				X	
sunshine			X		
cinema			X		
museums					X
libraries					X
theatres	X				
popchange		X		X	
age1564	X				
nateu		X			
femmales				X	
fertility	X				
natprop		X			
natnoneu		X			

Five factors explain 75.58% of total variance.

The table shows the relationship with each factors with the variables.

X: Denotes relatively high, *positive* correlation with the factor.
X: Denotes relatively high, *negative* correlation with the factor.

Based on this data, the factors can be defined as follows:

F1: Human Capital (S&T) + Service Economy
F2: Diversity + Structural Capital
F3: Tertiary & Finance
F4: Hospitals, Students, Dec. Population
F5: Culture + ICT Manufacture

[Eurostat + OECD] — Regressions: Setup

Output and Control Variables

Type		Context	Code
Output	GDP per capita in PPPs (USD)	Metropolitan	GDP
Control	Employment Rate (%)	Metropolitan	EMP
Control	Labor Productivity (USD)	Metropolitan	PROD

Definitions

Model	Expression
1	$GDP_i = \sum_{j=0}^{5} \beta_j F_{ji} + c + \epsilon$
2	$GDP_i = \sum_{j=0}^{5} \beta_j F_{ji} + \beta_6 EMP_i + c + \epsilon$
3	$GDP_i = \sum_{j=0}^{5} \beta_j F_{ji} + \beta_6 EMP_i + \beta_7 PROD_i + c + \epsilon$

[Eurostat + OECD] — Regressions: Results

Variables	Coefficients		
	Model 1	Model 2	Model 3
F1	.0328**	.0342**	.0185***
	(.0125)	(.0148)	(.0037)
F2			
F3	.0476***	.036**	
	(.0104)	(.0121)	
F4			
F5			
EMP		.0118**	.0076***
		(.0053)	(.0018)
PROD			.772***
			(.0724)
c	4.496***	3.410***	
	(.0175)	(.489)	
Obs.	20	20	20
R-sq.	0.47	0.62	0.96

Note: Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

- F1 (Human Capital + Service Economy) has a significantly positive correlation with GDP per capita. This effect remains consistent in all the models.
- F3 (Commercial Economy) has a positive and significant relationship. However, this effect is lost when considering productivity levels.

[Eurostat + OECD] — Rankings

	Criteria			
	HC+SE Index	Productivity	Employment	GDP per Capita
Copenhagen	**1**	13	3	10
Stockholm	**2**	10	5	4
Paris	**3**	2	16	2
London	**4**	1	9	1
Helsinki	**5**	12	8	8
Lyon	**6**	3	14	6
Munich	**7**	11	4	7
Berlin	**8**	19	20	20
Frankfurt	**9**	9	10	9
Lille	**10**	15	19	17
Vienna	**11**	4	13	3
Hamburg	**12**	8	15	13
Lisbon	**13**	16	12	15
Madrid	**14**	14	7	14
Budapest	**15**	18	2	18
Valencia	**16**	20	18	19
Barcelona	**17**	17	17	16
Rome	**18**	5	11	11
Turin	**19**	7	6	12
Milan	**20**	6	1	5

[OECD + PwC] — Dataset B

Sources

- (18) Indicators [2003-2010]: PricewaterhouseCoopers & OECD (Metropolitan and Regional Statistics)
  - (9) Science and Technology
  - (5) Human Capital
  - (4) Demographics
- (3) Output and Control Variables [2005]: OECD (Competitive Cities in the Global Economy)

16 Cities

1. Berlin
2. Chicago
3. Houston
4. Istanbul
5. London
6. Los Angeles
7. Madrid
8. Mexico City
9. New York
10. Paris
11. San Francisco
12. Seoul
13. Stockholm
14. Sydney
15. Tokyo
16. Toronto

[OECD + PwC] — Factor Analysis

	F1	F2	F3	F4
copat	X			
dofp		X		X
fodp		X		
patapp	X			
copat-national				X
copat-foreing		X		
patappict	X			
pop			X	
class		X		
entrepreneur	X			
libraries		X		
educ	X			
uni	X			
rnd	X			
tertiary	X			
vehicles	X			
murder			X	
doctors			X	

Four factors explain 76.16% of total variance.

Based on this data, the factors can be defined as follows:

F1: Human Capital + Structural Capital
F2: Transfer of Structural Capital
F3: Demographics
F4: Domestic-centered Structural Capital

[OECD + PwC] — Regressions: Setup

Output and Control Variables

Type		Context	Code
Output	GDP per capita in PPPs (USD)	Metropolitan	GDP
Control	Employment Rate (%)	Metropolitan	EMP
Control	Labor Productivity (GDP per worker, USD)	Metropolitan	PROD

Definitions

Model	Expression
1	$GDP_i = \sum_{j=0}^{4} \beta_j F_{ji} + c + \epsilon$
2	$GDP_i = \sum_{j=0}^{4} \beta_j F_{ji} + \beta_5 EMP_i + c + \epsilon$
3	$GDP_i = \sum_{j=0}^{4} \beta_j F_{ji} + \beta_5 EMP_i + \beta_6 PROD_i + c + \epsilon$

[OECD + PwC] — Regression: Results

Variables	Coefficients		
	Model 1	Model 2	Model 3
F1	.4037**	.3982**	.1331***
	(.0551)	(.03911)	(.0299)
F2	.1453*	.1358*	.0607*
	(.0623)	(.0666)	(.0275)
F3			
F4			
EMP		.0269**	.0118***
		(.0070)	(.0027)
PROD			.7921***
			(.0773)
c	10.389***		5.904***
	(.0665)		(.3093)
Obs.	16	16	16
R-sq.	0.78	0.83	0.99

Note: Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

- F1 (Human & Structural Capital) is highly significant in the three regressions. Its coefficient is greater in magnitude than that of the HC+SE in the previous dataset.
- F2 (Transfer of Structural Capital) reports a slight significance.
  - Its coefficient's value is less than a half in comparison to F1, meaning the relationship between the H&SC index and GDP per capita is stronger.

[OECD + PwC] — Rankings

	Criteria				
	H&SC	H&SC & SC Transfer	Productivity	Employment	GDP per Capita
San Francisco	**1**	2	1	3	1
Stockholm	**2**	1	8	10	8
Los Angeles	**3**	6	3	6	6
New York	**4**	5	2	7	2
Chicago	**5**	8	7	9	5
Paris	**6**	4	6	14	7
Tokyo	**7**	13	11	5	11
Houston	**8**	9	4	8	3
Toronto	**9**	3	12	12	10
Seoul	**10**	14	14	2	14
Sydney	**11**	7	9	4	9
Berlin	**12**	12	13	16	13
Madrid	**13**	10	10	11	12
London	**14**	11	5	13	4
Istanbul	**15**	16	16	15	16
Mexico City	**16**	15	15	1	15

Preliminary Observations

1. The Intellectual Capital perspective can help improve the framework for classifying cities and building indices.
    - E.g., European cities oriented towards service economies tend to have higher levels of human capital.

2. Among all variables considered, those pertaining to *Human Capital* are essential to the "best" indices.

3. These indices complement Employment and Productivity rankings in the explanation of the success of creative cities.

4. Further studies should explore other output variables and data grouping techniques.

5. Poorness and heterogeneity of the data remains a big issue. More surveys and standardization is needed,

Part II
Structural Patterns in Complex Innovation Systems

Background 1/2

The Open Innovation Paradigm

"The use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively." [Chesbroug et al., 2006]

- **Systemic Qualities:** Involves various agents: firms, universities, public institutions...

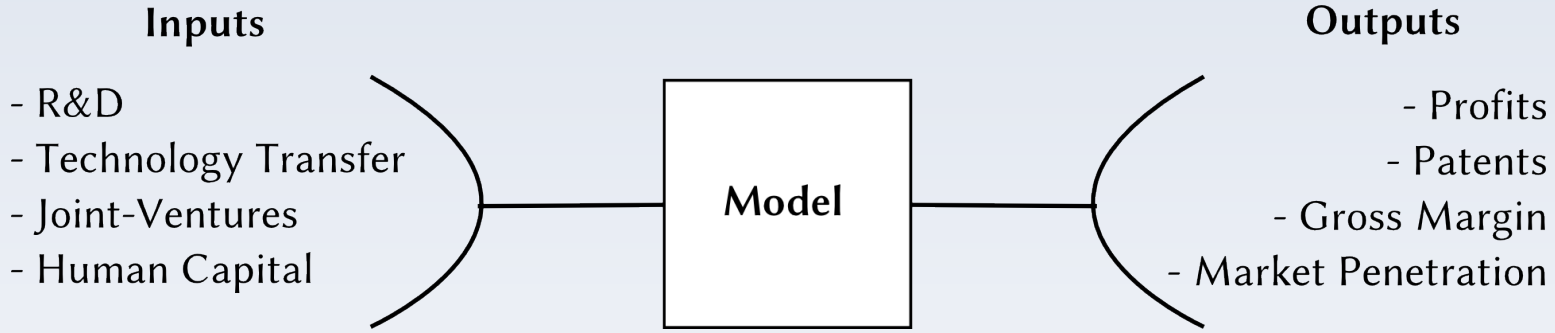
The Concept of Innovation Systems

"The network of institutions whose activities initiate, import, modify and diffuse new technologies." [Freeman, 1987]

- Applied by World Bank and OECD in policy directives.

Background 2/2

- Whereas the IS approach is network-oriented, most studies on innovation are input-output based.



- This framework does not consider complementarity effects.

How to measure Innovation Systems?

The difficulties involved in the quantification of specific linkages between institutions have hindered empirical analyzes [Carlsson and Rickne, 2002].

Enter *Complexity...*

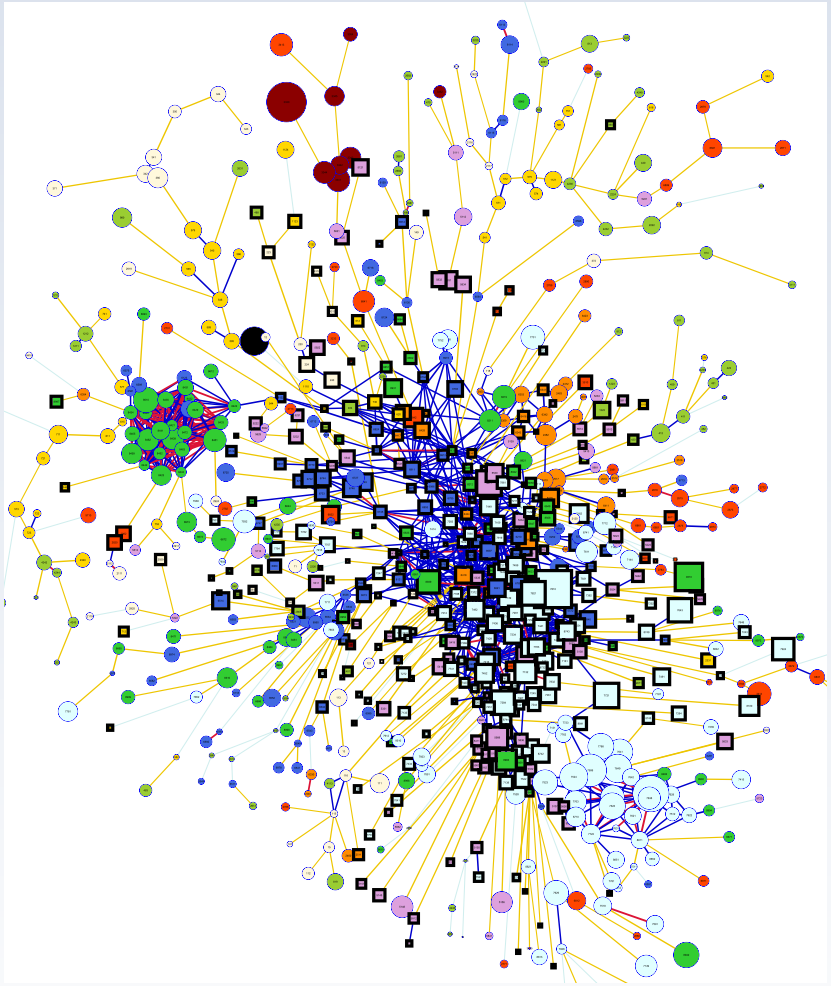
...as a tool for the representation of knowledge networks.

Nodes: Firms.
Interactions (link): a proximity measure based on a variable which represents the capacity of the firm to interact with the system.

E.g, Outward R&D Expenditure (CIS)

$$RCA(s,i) = \frac{\frac{x(s,i)}{\sum_i x(s,i)}}{\frac{\sum_s x(s,i)}{\sum_s \sum_i x(s,i)}}$$

$$\phi_{ij} = min\{RCA(s,i), RCA(s,j)\}$$



[Hidalgo CA. Klinger B, Barabasi A-L, Hausmann.R, 2007]

Multilevel Analysis

Metrics

Degrees of Connectivity, Distances, Rates of Difussion, Clustering...

- **Firm-level:** What configurations of Open Innovation? Relationship between connectivity and profits?
  - Benchmark with other firms.
- **Sector-level:** Relationship between connectivity and sector performance?
  - Benchmark with other countries.

Thank You

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