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Open Innovation Network: the case of Healthcare firms of Nasdaq-100 Index

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Introduction and contribution to literature

- This paper fills the gap in literature by exploring the use of the SNA approach in empirical research on cooperation among Nasdaq-100 healthcare companies in the 1995-2014 patent range.
- Study of the healthcare sector by analyzing the patents protected under partnerships in order to classify the firms into an open innovation (OI) matrix and map the configuration and scope of their cooperation networks.
- Showing discussions on the evolution of investments in R&D and the technological fields prioritized by companies.

Literature Research

OI and cooperation network	The use of patents as a measure of innovation activities	Social Network Analysis (SNA) and Cooperation Networks
<p>The form of OI adopted can vary significantly from company to company. (Lindegard, 2010);</p>	<p>Patent is the only source of standard information on new technology possible of being systematically collected over a long period of time. (Lööf and Nabavi, 2015);</p>	<p>Use of SNA to analyze phenomena related to innovation has been increasing. (MONTRESOR; MARZETTI, 2009; HELMS et al., 2010);</p>
<p>The need for more research on the "gray areas" between fully open and fully closed innovation. (Leminen et al., 2015).</p>	<p>Patents are considered a proxy that reflect technological advancement. (YOON; PARK; KIM, 2013).</p>	<p>SNA studies the relationships among a set of actors with the aim of detecting models of social interaction. (Jamali and Abolhassani, 2006).</p>

Objectives

- Deepening on OI studies by understanding:
 - how healthcare firms of the Nasdaq-100 Index cooperate among themselves by means of analyzing the cooperation network
 - study their R&D investments.
- To apply an OI matrix on these firms in order to classify them in different degrees of OI.

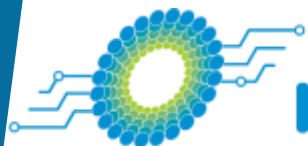
The Nasdaq-100 Index

- Differs from traditional stock exchanges because it is an electronic stock exchange, in which only shares of technology companies known as "New Economy"
 - companies such as Apple, Google, Microsoft, Intel and others are traded.
- Includes the top 100 US and international non-financial companies listed on the stock market (market capitalization).
- The index reflects companies in all major industry groups, including hardware and software, telecommunications, retail/wholesale and biotechnology.
 - The index doesn't contain securities of financial companies, nor investment companies.
- Because of the NASDAQ-listed high technology industry, the index movement is heavily influenced by what is happening in these industries.
- At the time of data collection the index was formed by 4 segments: 56% Technology, 18% Services, **16% Healthcare** and 10% Consumer Goods.

Materials and Methods

- The sample consisted of the 10 healthcare companies of the Nasdaq-100 Index that deposited patents between 1995 and 2014 individually or in co-ownership.
- The patents were extracted from the Derwent Innovation database by Clarivate Analytics
 - search in the field "Assignee" (transferee or owner who benefits from the patent) that allowed to identify other organizations that were listed as patent co-owners.
 - Focus are interorganizational innovation networks, thus, the names of individuals were excluded from the Assignee database
- Information on R&D investments was obtained through the Thomson Reuters One for the same period.

Results and Discussions



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Quantity of INPADOC's in partnership

Companies	Subsector	INPADOC's (patent families)				
		Individual	%	Co-ownership	%	TOTAL
Mylan , N.V.	Pharmaceuticals	75	21	282	79	357
Celgene Corporation	Pharmaceuticals	192	39	300	61	492
Illumina, Inc.	Biotechnology	Amgen has, by far, the greatest number of patents				359
Gilead Sciences, Inc.	Biotechnology	Amgen has, by far, the greatest number of patents				589
Amgen Inc.	Biotechnology	791	54	673	46	1.464
Biogen Inc.	Biotechnology	334	64	189	36	523
Alexion Pharm. Inc	Pharmaceuticals	84	82	19	18	103
Intuitive Surgical, Inc.	Medical Equipments	245	87	38	13	283
Regeneron Pharm. Inc	Pharmaceuticals	181	87	27	13	208
Vertex Pharma. Inc.	Pharmaceuticals	565	89	69	11	634
Median shows less than 50% cooperation				Median % :	41	5.012

Investments in R&D

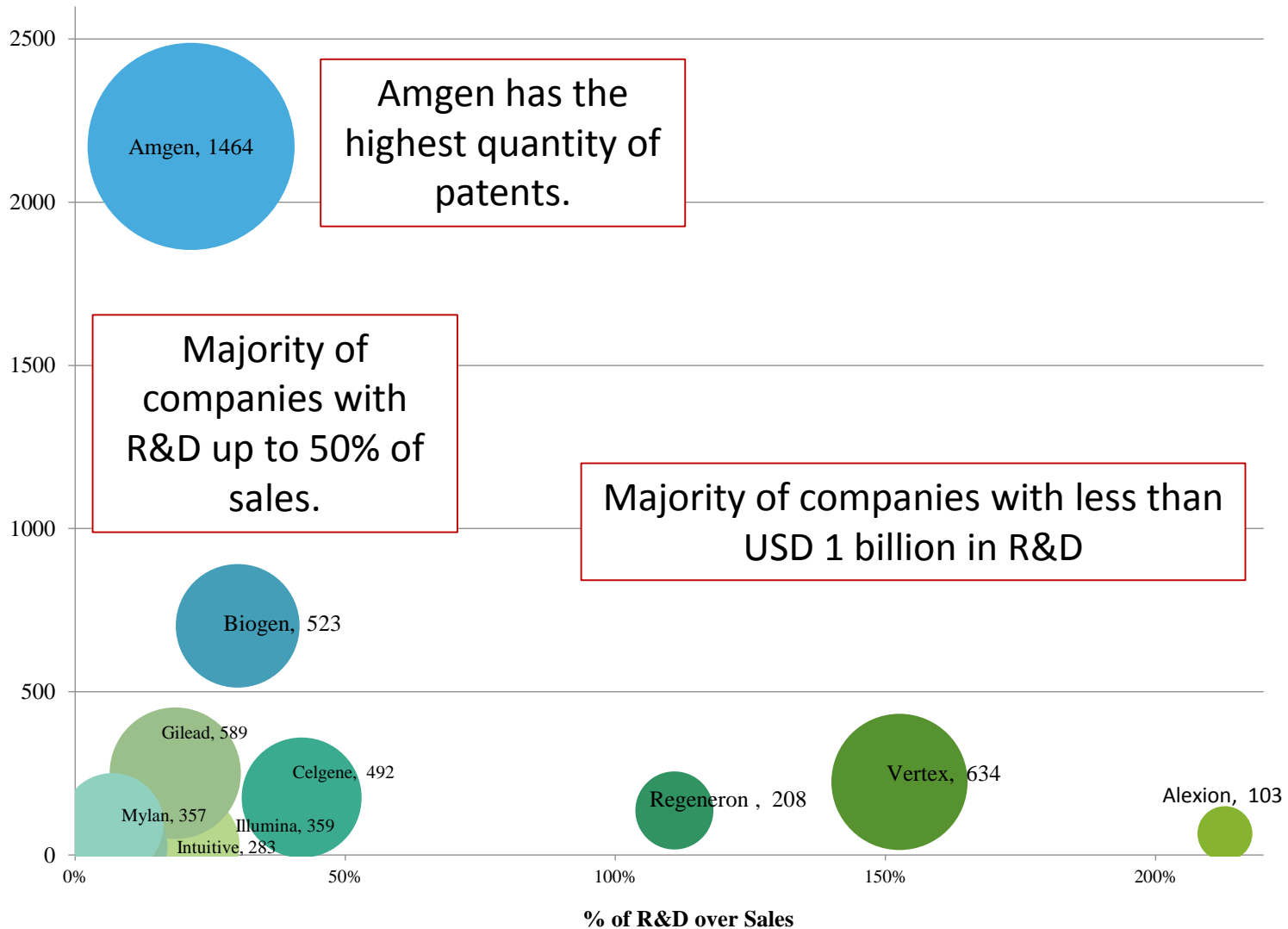
Companies:		Total Investment in R&D (Amounts in USD MM)				CAGR
		2014	Medium 1995-2014			
Alexion	<p>Amgen invested the highest R&D volume in 2014 among all companies.</p> <p>The company also has the highest median volume in R&D in 20-year period.</p>	<p>Companies investing more than 100% of sales in R&D .</p>	65.77			
Vertex			224.09			
Regeneron			136.58			
Celgene.			2430.60	175.84		
Biogen.			1893.42	702.13	523	11.85
Amgen	21.5	4297.00	2171.00	1464	-0.97	
Illumina	20.9	386.55	33.37	359	11.57	
Gilead	18.5	2854.00	250.64	589	2.16	
Intuitive Surgical	8.7	178.00	26.49	283	21.59	
Mylan	6.9	563.90	94.53	357	13.17	

Amgen has the greatest amount of patents, however not the highest CAGR.

However, the highest CAGR belongs to Intuitive Surgical, with the lowest investment in R&D.

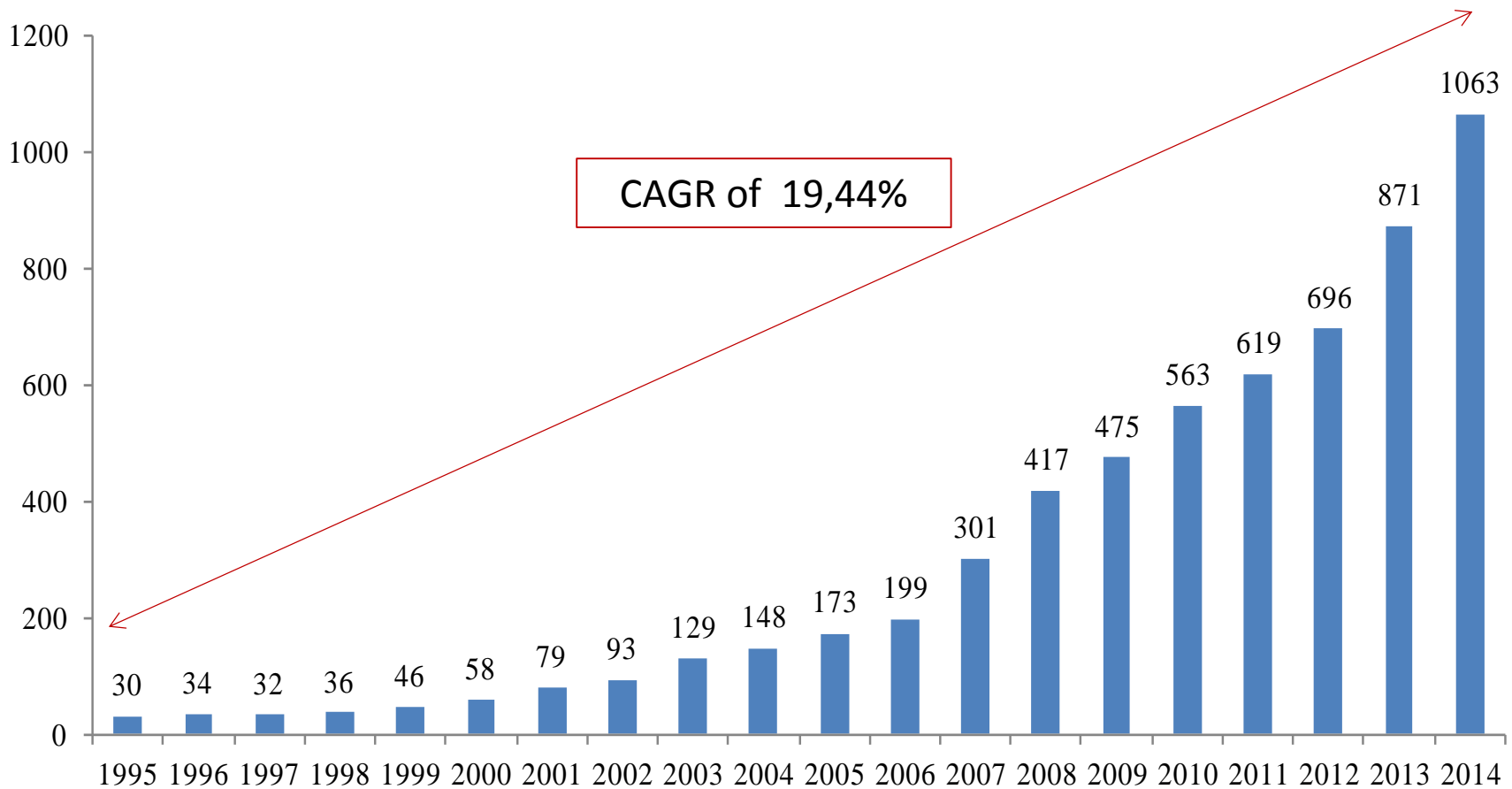
Investments in R&D and quantity of INPADOC's 1995 - 2014

Investment in R&D
USD millions

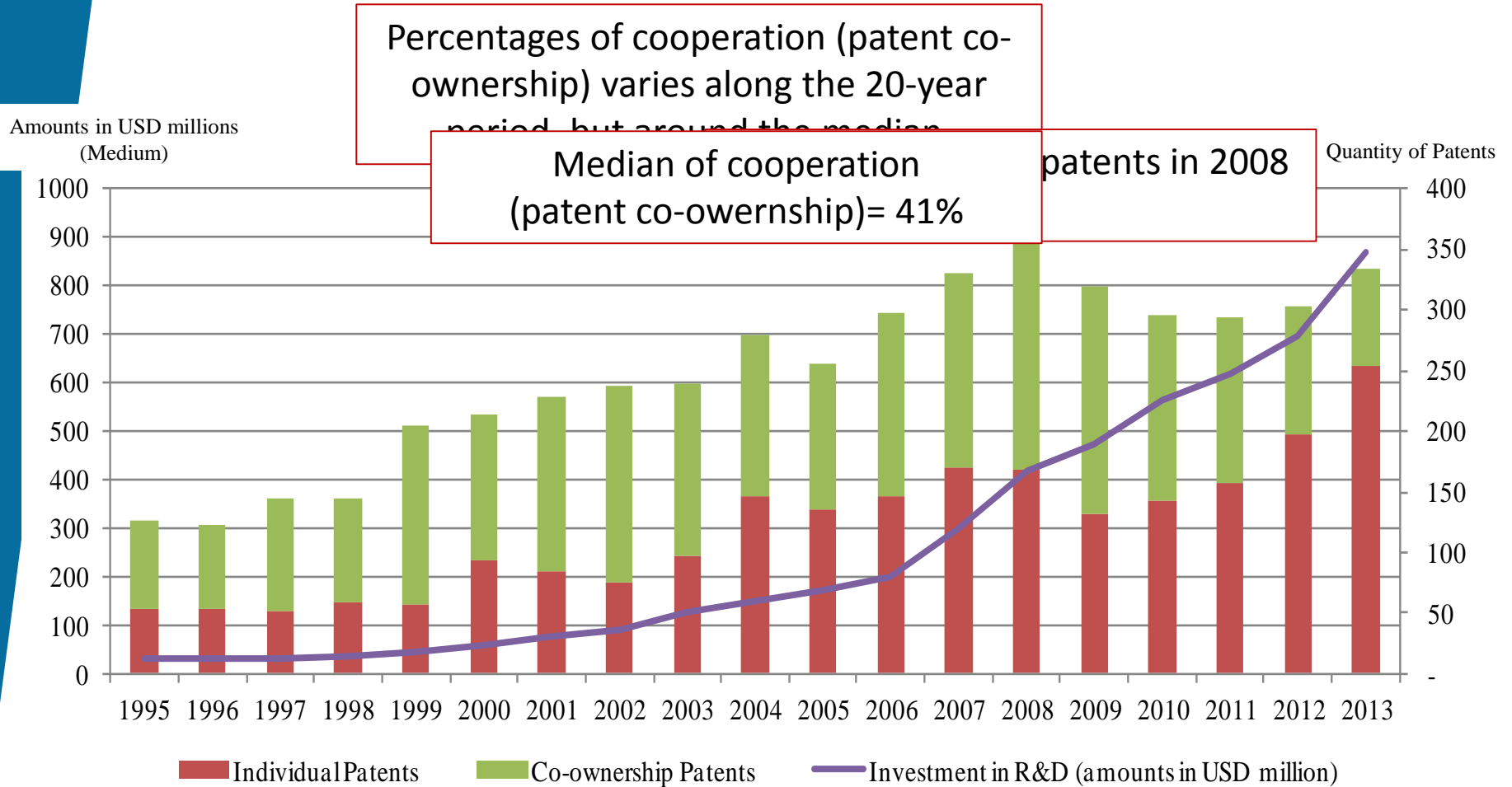


Evolution of Investments in R&D of the Healthcare segment

Amounts in USD millions
(Medium)



Evolution of Healthcare partnerships

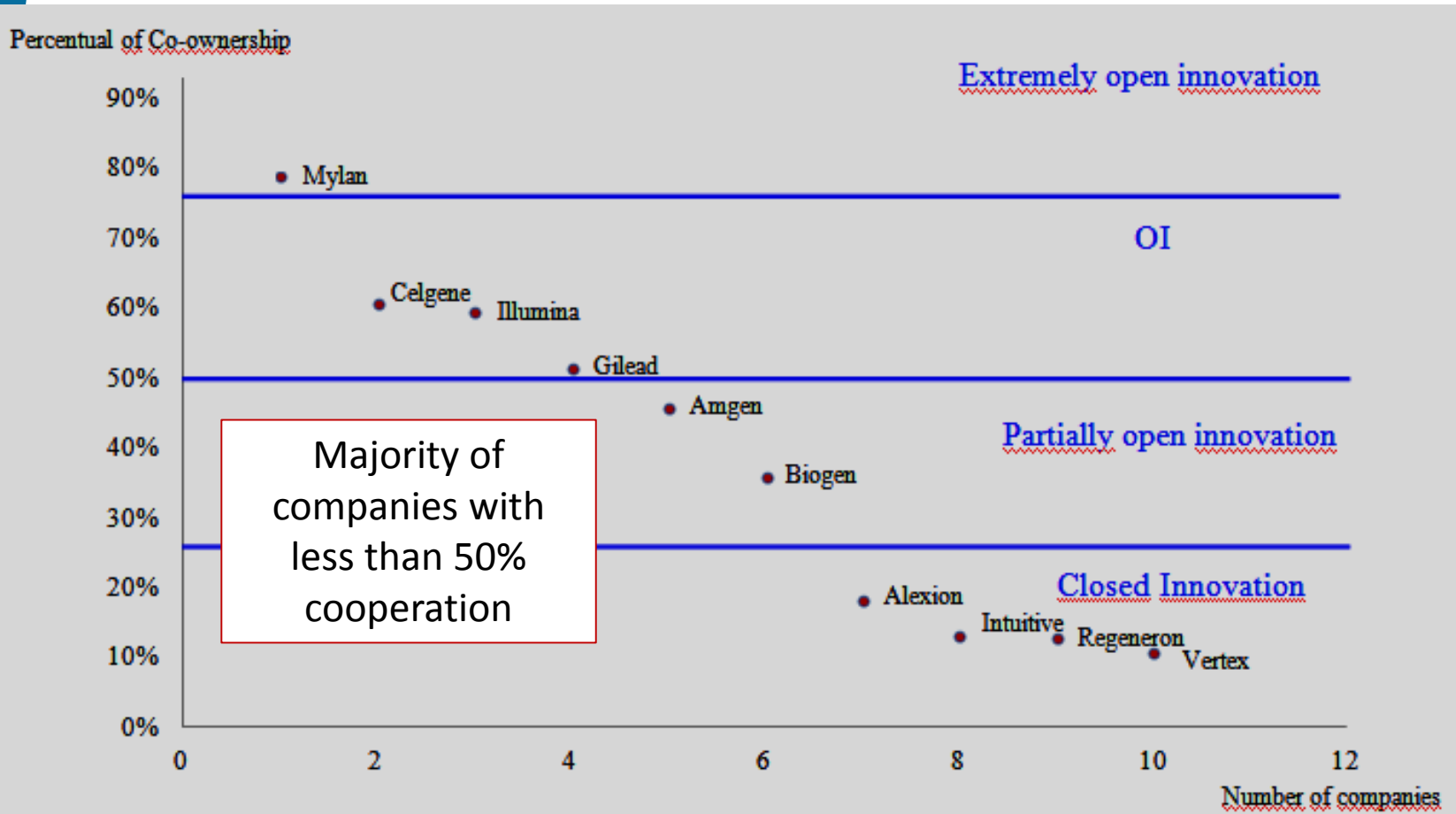


Matrix of Open Innovation

Quartiles:	Practices of the companies:	Classification:
0 – 25%	Employs proprietary technology	Closed Innovation
26% - 50%	Prioritize interactions and partnerships sporadically	Partially open innovation
51% - 75%	Make constant and regular use of partnerships in internal and external R&D investments	OI
76% - 100%	Develop technology through partnerships and collaboration networks	Extremely open innovation

The study shed lights on the discussion of grey areas of OI.

Classification of companies in relation to OI 1995 - 2014



Classification of companies as to the degree of OI

Period: 1995 - 2014

Quartiles / Companies	Investment in R&D - USD MM	Patents in co-ownership (%)				CAGR (%) (1)	
		0 - 25%	26 - 50%	51 - 75%	76 - 100%	Patents	Investment in R&D
Mylan	94,5				79	13,17	15,70
Celgene	175,8			61			
Illumina	33,4			60			
Gilead	250,6						
Amgen	2.171,0		46			97	11,92
Biogen	702,1		36			85	22,27
Alexion	65,8	18				-8,58	25,14
Intuitive Surgical	26,5	13				21,59	15,05
Regeneron	136,6	13					22,13
Vertex	224,1	11					16,33

Few companies with more than 0% cooperation.

CAGR of patents vary among companies.

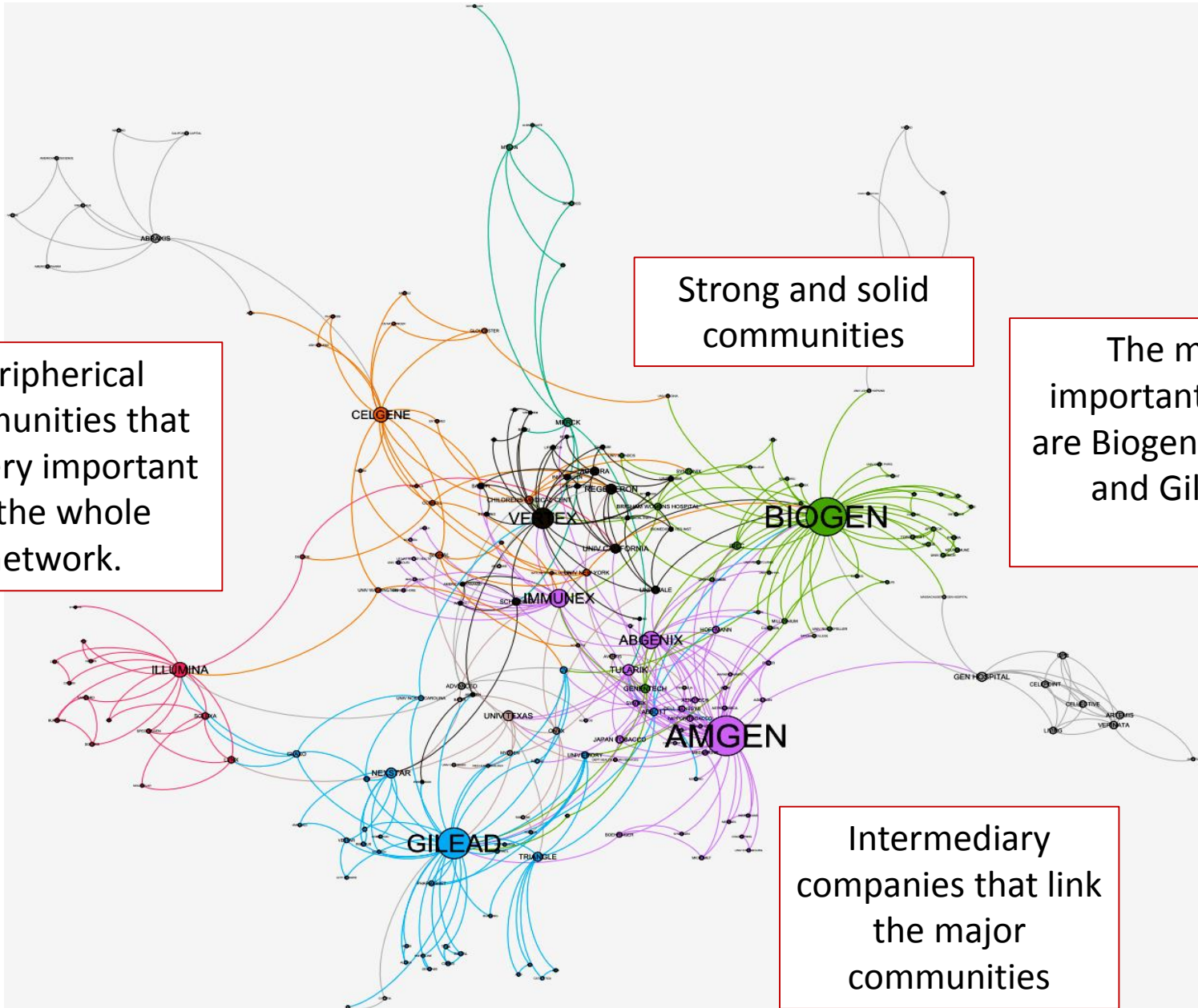
Consistent CAGR in R&D.

(1) stock market performance indicator

Measures of cooperation network of companies in the Healthcare segment

Metrics	Value	
Average Degree	3.094	
Weigthed Average Degree	7.59	
Network Diameter	10	High network Diameter
Graph Density	0.008	
Modularity	0.767	
Connected components	22	Plenty of connected components
Average Clustering Coefficient	0.637	
Average path length	3.904	High average number of steps

Cooperation network of Healthcare companies



Peripheral communities that are very important to the whole network.

Strong and solid communities

The most important nodes are Biogen, Amgen and Gilead.

Intermediary companies that link the major communities

Main characteristics of the network

- It is a distributed network, thus not centered around an specific company;
- It has plenty of communities, being the main ones around Biogen, Amgen and Gilead;
- There is no concentration in any side of the network;
- Small communities allow links that connect all firms;
- The network contains companies that do not belong to Nasdaq-100 Index;
- It is a global structure that affords the flow of innovation knowledge.

SNA descriptive statistics of healthcare companies and partner organizations with higher degrees

Company:	Average Degree	Weighted Average Degree	Number of Triangles
Amgen	84	271	44
Biogen	76	192	23
Gilead	47	167	28
Vertex	27	62	21
Immunex	24	34	15
Abgenix	22	79	24
Celgene	22	50	7
Illumina	20	67	15
Tularik	15	74	11
Regeneron	15	32	3

The higher stats belong to the most important nodes in the network.

Companies are ranked by Average Degree.

Ties with higher weights in the healthcare network

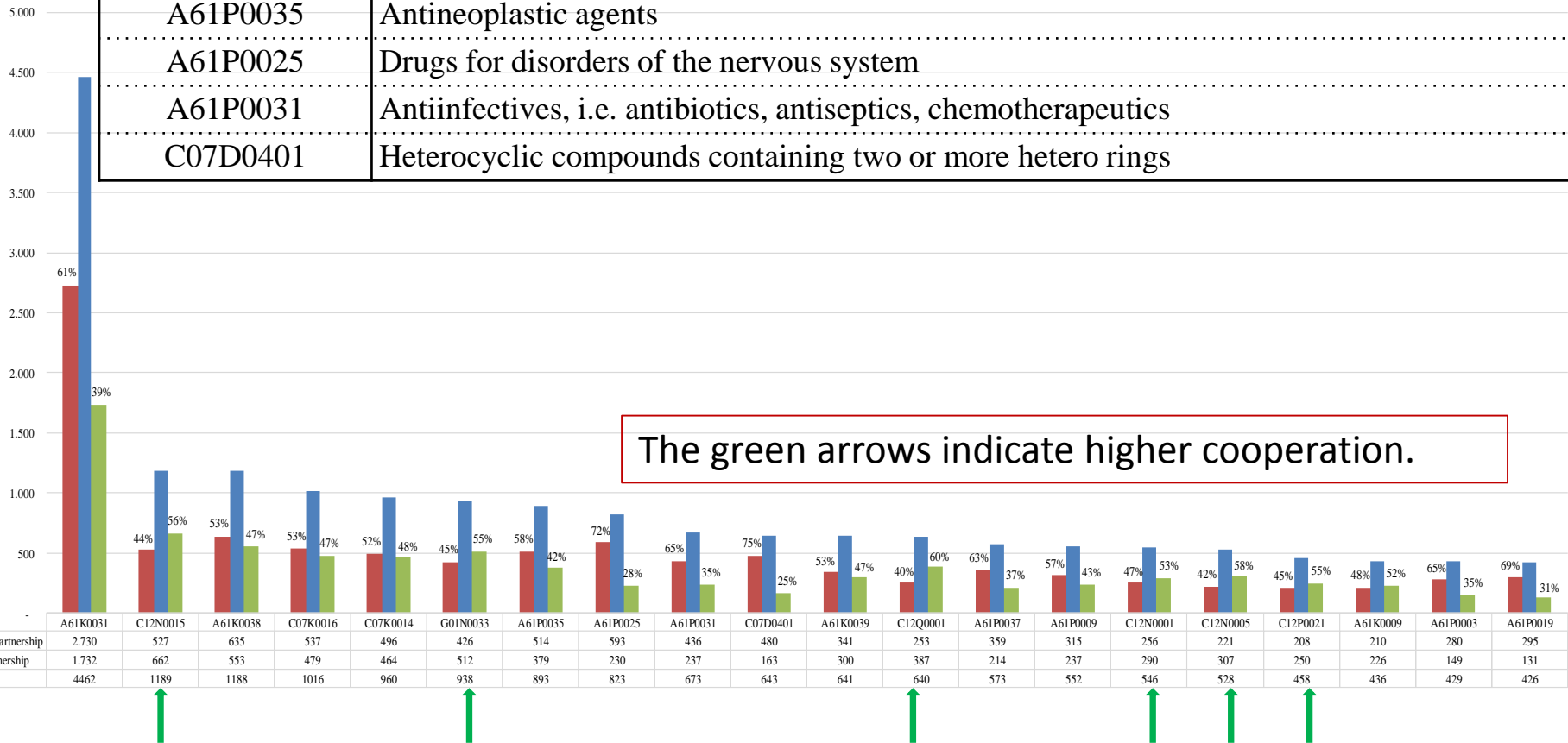
Assignee A	Assignee B	Weight
Mylan	Generics	67
Amgen	Tularik	48
Gilead	Cv	48
Biogen	Idec	37
Amgen	Abgenix	35
Illumina	Solexa	31
Mylan	Matrix	31
Amgen	Micromet	26
Merck	Generics	23
Cytopia	Ym	14

Mylan composes the highest weighted pair, since it is the company with the highest degree of OI.

The main pairs of assignees contain firms that do not belong to Nasdaq-100 Index, but are highly relevant to the connectivity of the network.

Main groups of IPC's of the Healthcare segment patents

IPC-Group:	Description:
A61K0031	Medicinal preparations containing organic active ingredients
C12N0015	Mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors
A61K0038	Medicinal preparations containing peptides
C07K0016	Immunoglobulins, e.g. monoclonal or polyclonal antibodies
C07K0014	Peptides having more than 20 amino acids
G01N0033	Investigating or analysing materials by specific methods not covered by groups
A61P0035	Antineoplastic agents
A61P0025	Drugs for disorders of the nervous system
A61P0031	Antiinfectives, i.e. antibiotics, antiseptics, chemotherapeutics
C07D0401	Heterocyclic compounds containing two or more hetero rings



Technological areas

- The group A61K0031-Medicinal preparations containing organic active ingredients is predominantly proprietary (61%).
 - This may indicate the industry's focus on protecting knowledge related to medicinal formulations or compositions containing ingredients therapeutically of organic actives for use in medical application and use of these organic compounds for the treatment of pathological conditions of the patients.
- The business strategy for these IPC groups is focused first on proprietary technology and second on collaborative development.
- However it was found a strong interest of companies in expanding their research in these field in a collaborative way, which results in the formation of clusters in the network

Conclusions

- With regards to OI Matrix, the companies are distributed along the quartiles
 - however, only one company is classified as extremely OI (Mylan);
- The main technological areas prioritized by the companies, with the greatest development of **proprietary technology**, are:
 - Medicinal preparations containing organic active ingredients;
 - Medical preparations containing peptides;
 - Immunoglobulins, e.g. monoclonal or polyclonal antibodies
- The technological areas **developed in cooperation** are :
 - Mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors
 - Investigating and analysing materials by specific methods not covered by groups
 - Measuring or testing processes involving enzymes or micro-organisms
- There is a diversity of actors works in partnership for the **development of technologies**
 - forming a cooperation network that has as its main characteristics:
 - network with many interactions
 - high score of modularity.

Limitations and future studies

- Only the companies in the health sector that integrate NASDAQ index were analyzed
- Companies in this industry engage in cooperation with several companies in other sectors that are not listed on NASDAQ
- In future studies it is expected:
 - apply dynamic SNA to assess how the cooperation networks are constituted over the period
 - analyze all companies in the pharmaceutical and biotechnology sector

