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Can R&D spending guarantee innovativeness?

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Instructor : Prof. Tugrul U. Daim

Team 1 Members :

Momtaj Khanam
Supreet Bose
Paweena Kongsansatean

Table of Contents

Abstract

The term “Innovativeness” confers both technological and market impetus of a firm. There is a plethora of factors given by different literatures behind a firm’s innovativeness. However, the most frequently argued concept is trying to correlate R&D spending to innovativeness. This paper tries to give insights to what extend R&D spending relates to “Innovativeness” through literature review and also considering R&D expenditure to be one of the most important input element of innovation, compared R&D performance of top nine most innovative companies by Booz and Co. Apple being the most innovative company has very few patents compared to IBM, Samsung and other firms and also in terms of collaboration and business diversity. R&D intensity is a measure of corporate reputation which may have an impact on innovation that can effect company’s ranking as most innovative.

1.Introduction

Innovation is a discovery that has survived laboratory experimentation and escaped to production and adds economic value even if it is simply cost saving.[1]A logical deduction is that more and more experimentation in the form of research and development would increase the prospect of discovery turning into innovations. However, there are conflicting notions regarding R&D spending and Innovation. Investment in R&Dand other intangibles such as investments in software, higher education, and worker training are key inputs driving innovation. Analysisof amount of investment in R&D and product and process innovation for a broad cross section of industries have shown a positive correlation between Index of Industry Innovation rate (index is created by adding the number of product and process innovations for each industry in a National Science Foundation database) against R&D intensity (the ratio of R&D expenditure to sales).[2]

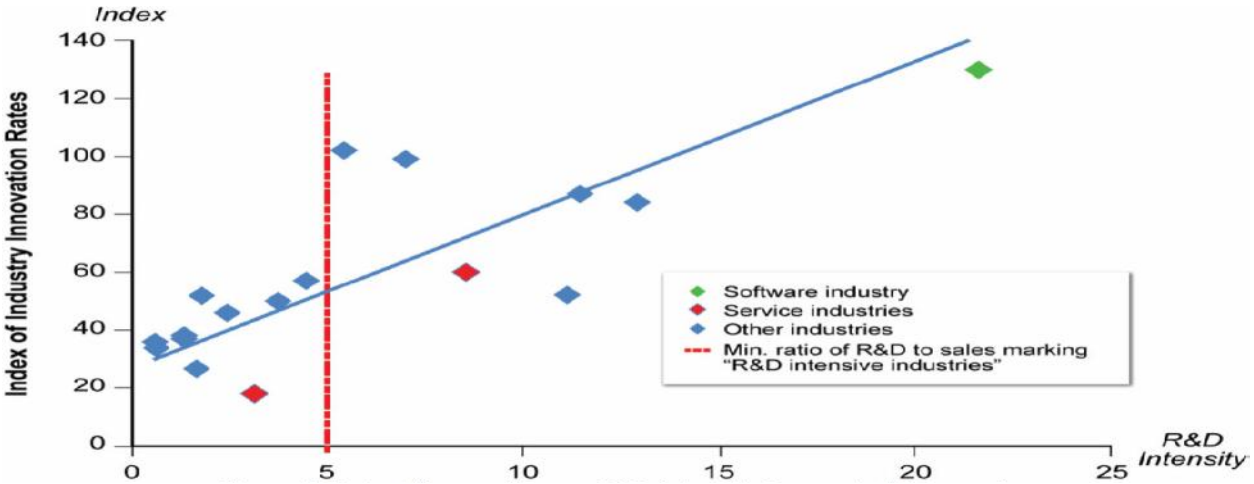

Figure 1: Rate of Innovation vs. R&D Intensity Percent of Companies in an Industry Reporting Product/Process Innovation

However, several business magazines and consulting firms, for example, Forbes, Fast Company, Bloomberg Businessweek, Booz & Company comes up with their list of innovative companies and their R&D expenditures each year. From these insights it is revealed that R&D spending does not ensure increased financial gains, nor does it guarantee innovation success. Barry Jaruzelski,, senior partner at Booz & Company and global leader of the Engineered

Products & Services categorically denies any long term correlation between amount spent on innovation and an organization's overall financial success," Figure 2 shows the Innovativeness and R&D expenditures of companies within the top 10 of Booz and Co. list of Most Innovative Companies and their R&D spending for the year 2008 – 2012. However, as there is no list of Most Innovative Companies for 2008 and 2009, the data set is collected from Forbes, which seems to be the most consistent with Booz& Co list.

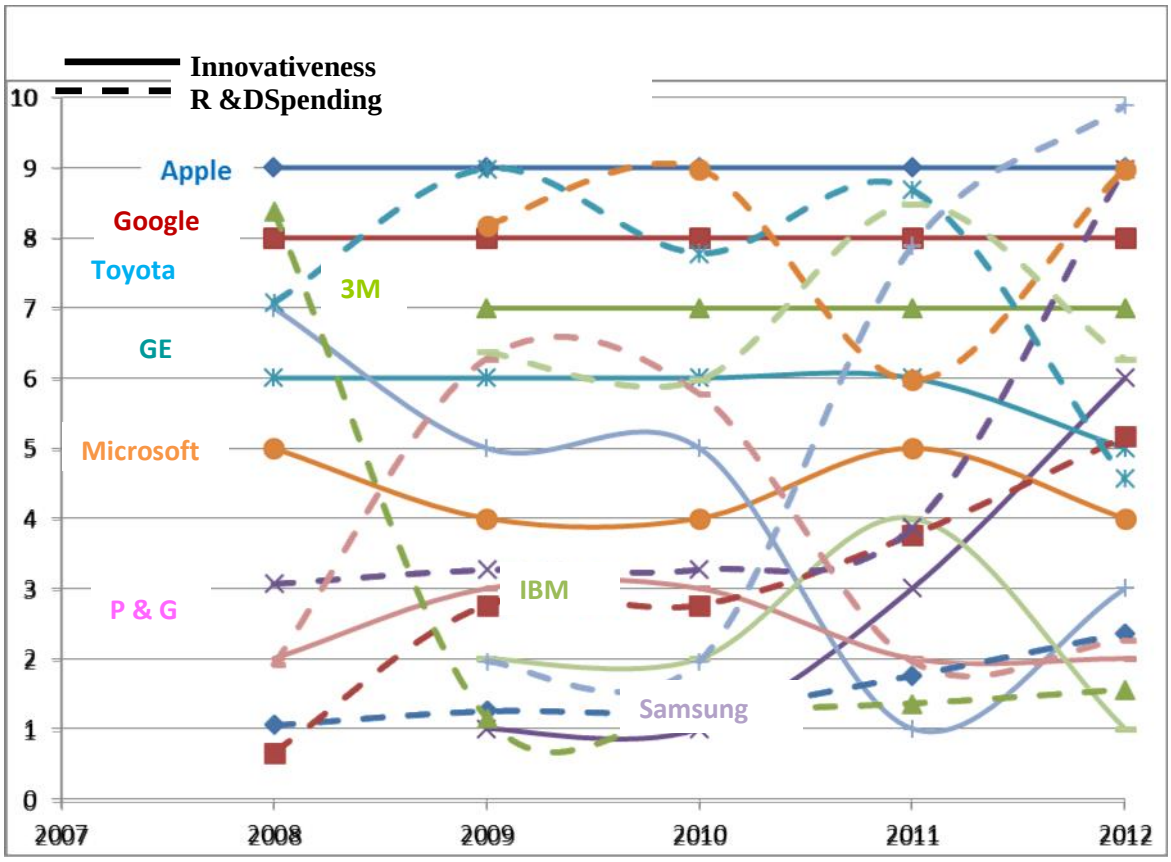

Figure 2: Innovativeness and R&D Spending of Top 9 Companies by Booz & Co.

Booz & company, a global management consulting firm, has ranked the list of the most innovative companies compare to the most R&D spending companies since the year 2010. The significant information shows that those 2 lists are almost different in the name of companies and we find that only 3 companies in the most R&D spending are in the list of the most innovative firms 3 years straight, moreover the top three of the most innovative list are constant since 2010. A question comes to our mind, "why is the most R&D spender not the most innovator?"

The Most Innovative companies 2010-2012						
# rank	2010		2011		2012	
	Companies	R&D spend ($ billions)	Companies	R&D spend ($ billions)	Companies	R&D spend ($ billions)
1	Apple	1.3	Apple	1.8	Apple	2.4
2	Google	2.8	Google	3.8	Google	5.2
3	3M	1.3	3M	1.4	3M	1.6
4	GE	3.3	GE	3.9	Samsung	9.0
5	Toyota	7.8	Microsoft	8.7	GE	4.6
6	Microsoft	9.0	IBM	6.0	Microsoft	9.0
7	P & G	2.0	Samsung	7.9	Toyota	9.9
8	IBM	5.8	P & G	2.0	P&G	2.0
9	Samsung	6.0	Toyota	8.6	IBM	6.3
10	Intel	5.7	Facebook	N/A	Amazon	2.9

Table 1: The most innovative companies 2010-2012 by Booz & company.

The interesting information from Booz's list is:
1. Apple, Google, and 3M have been standing constantly in the list 3 years straight.
2. Samsung has risen up and skip up year by year.
3. The first 9 companies have been standing in the list every year.

The purpose of the study is to find out the factors which lead to innovativeness through different literature reviews and clarifying the fit-in of R&D spending in firms' innovativeness.

2. Literature Review

2.1 What is Innovativeness

With the turn of this century our life has become more "technologized' by the rapid innovation of products and services by industrial firms and enterprises. Innovativeness has become the norm of making business successful. Innovativeness is defined as a firm's ability to perform innovation or production of new products, processes or ideas.[3] Although, innovation and innovativeness are frequently used interchangeably, few authors clarified the two terms having no correlation. Innovation is argued to be related to innovation just as productivity to production.[4] The function innovation is considered to equate with two variables: technical and administrative. Product and process innovation is part of technical variable while administrative variable consists of business system or processes.[5] Product innovativeness not always imply firm's innovativeness. There are many organizations develop technology based on existing technology that can lead to commercial success. The firm is innovative if it has broken the chain of existing marketing resources, technological resources, skills, knowledge, capabilities, or strategy of the firm.[1]. But in most literatures innovation and innovativeness is used interchangeably.[6,7] Firm's innovativess can be determined by clarifying if the product is considered new and unfamiliar to and customers and whether thetechnologies or procedures adopted for the production of the product are new.[8]

2.2 Evolution of Innovation Metrics

According to Milbergs and Vonortas (2004) [9] different criteria have been used for measuring innovation through out the history. The metrics developed at different time period can be divided into four stages. Table 1 shows the metrics considered for measuring innovativeness chronologically.

First Generation Input Indicators (1950s–60s)	Second Generation Output Indicators (1970s–80s)	Third Generation Innovation Indicators (1990s)	Fourth Generation Process Indicators (2000s plus emerging focus)
• R&D expenditures • S&T personnel • Capital • Tech intensity	• Patents • Publications • Products • Quality change	• Innovation surveys • Indexing • Benchmarking innovation capacity	• Knowledge • Intangibles • Networks • Demand • Clusters • Management techniques • Risk/return • System dynamics

Source: Milbergs and Vonortas, 2004

Table 2 :Examples of evolution of innovation metrics by generation

- First generationmetrics considers variables that seem to have linear relationship with innovativeness.
- Second generation relates innovativenesss to outputs of science and technology (S&T) activities.
- Third generation metrics focus on factors that are outcome of surveys and makes use of publicly available data.
- Fourth generation metrics, reflects more on intangibles.

2.3 Models and Frameworks for Measuring Innovativeness

2.3.1 Comparison of Innovation Models

Different innovation models reflect on different perspective of innovation dimensions

Measure-mentModel	Example of Tools	Focus	Dimensions	Remarks
Diamond Model	Improve	- Innovation process - Enabling factors - Linkage	Strategy, Process, organization, Linkage and learning	Adequate when innovation process at its infancy. It highlights key dimensions of innovation process as well as its enabling institutional factors
Funnel Model		- Techenologyinno-vation or product innovation focus - R&D process as the Core activity	Strategic Thinking, portfolio Management and Metrics, Research, ideation; insight, Targeting; Innovation Development, Market Development; and Selling	Adequate model when there is a due innovation process in the organization
Innovation Value Chain (IVC)	- NESTA - Innovation for growth	- Idea management - Output performance	Generation, Conversion, Diffusion, Knowledge Acquisition, Building Innovation, Commercializing Innovation	Emphasizes the assessment of innovation process
Oslo Manual	- InnoCert - InnoBiz	- Innovation - Linkage - Output in certain duration	Innovation, Linkage, Demand, Infrastructure and institutional framework, and Innovation Policies	Very beneficial when considering country level international comparisons
	- Innovation Radar	- Innovation output performance	Offerings, customers, the output of processes, marketing	Does not ensure the sustainability of innovation process

Table 2: Summarized comparison between different innovation measurement models

2.3.2Innovation Framework by Science & Technology Policy Institute U.S.A

Innovation activities need both tangible and intangible inputs. Both inputs have cost involvement but one has physical personified while the other cannot be and is known as either:knowledge asset" by economic literature and "intellectual assets" by business literature**.**

Tangible Assets	Intangible Assets
Information and communications technology infrastructure	Patents
	Databases
Production materials	R&D progress
Production machinery and facilities	Organizational processes
	Knowledge and skills of labor force

Table 3: Tangible and Intangible [11]

Based on the concept of intangibles two types of innovation framework is proposed byRose et al.

Type of Asset	**Description**
Human Capital	Employer provided training
	Experience
Intellectual Capital	R&D
	Databases
	Movie development
	Music and book development
	Patent and license fees
	Trade secrets
Organizational capital	ICT Infrastructure
	Alliance and networks
	Marketing
	Business Models
	Design and prototyping

Table 4: Framework 1: Measuring Innovative Activity

Framework 1 considers intangible capitals resulting from innovation activities.In Framework 2, clarifies investments necessary forinnovation and growth. The framework concentrates on basic investments conducive to innovation.

Type of Asset	**Description**
Human Capital	Employer provided training
	Higher education
	Elementary secondary education
	Experience
Technical Knowledge	Scientific R&D
	R&D in social sciences and humanities
	Movie development
	Music and book development
ICT Infrastructure	Organizational Capital
	Website design

Table 5: Framework 2: Measuring Investments

2.4 HowR&D Spending Affects Innovation

Investment for innovation can be interpreted into spending for seven objectives.[12]

R&D	R &Dspending is on scientific research and development that produces new knowledge. This can be translated into ideas or products that can be marketed by firms.
Design	Sometimes investment in design is considered as 'non-scientificR&D'. However, if the design is intended for product and service development then it is scientific R&D. Design can also be directed for inventing new services and financial products.
Organizational improvement	Investment in this category improves efficiency and effectiveness. This helps organization to formulate strategies for exploiting innovative ideas commercially.
Training & skills development	Investment in educating employees through training and skills development turns them into human capital for the organization which is one of the most integral means for innovation.
Software development	Investment in software and database installation is important because it becomes an asset for the firm.
Market research & advertising	Investment is required to find out market potential of a new product and also to develop brands both of which are essential elements of innovation process.
Other (Copyright development and mineral exploration)	Intellectual property is a form of asset. This can be leveraged for financial gain for the firm

An interesting finding from research on investment by the UK private sector in 2007 was that R&D is significantly lower than other types of investment.innovation.

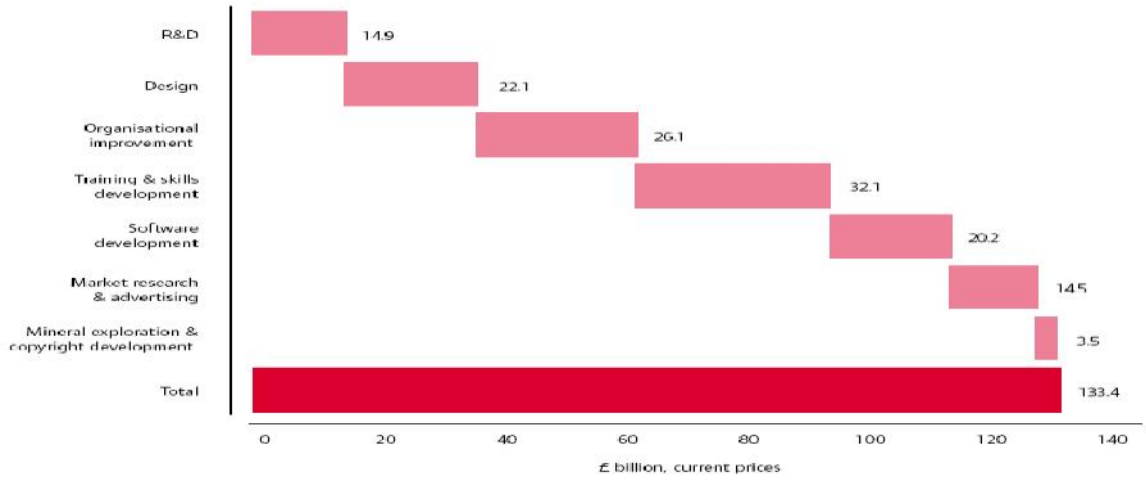

Figure 3: Investment in innovation, (£ billion), 2007

Figure 3 shows that R&D is only the fifth largest category of innovation investment, at 11 per cent of the total. It was found that 30 UK firms invest mostly in training the workforce: training and is one fourth of all innovation investment.

However, Research and Development (R&D) and product development metrics is one path to tangible measurement. Companies are focusing on innovation measures and tangible tools to boost their overall innovativeness. In a survey conducted by Goldense Group, Inc (CGI) on 200 companies revealed the top R&D metrics used in 2008 to be R&D spending as a percentage of sales.

The following are the top 10 R&D metrics used by industry (2008):according to CGI

- R&D spending as a percentage of sales (77 percent);
- Total patents filed/pending/awarded/rejected (61 percent);
- Total R&D headcount (59 percent)
- Current-year percentage sales due to new products released in the past six years

(56 percent);

- Number of new products released (53 percent);
- Number of products/projects in active development (47 percent);
- Percentage resources/investment dedicated to new product development (41 percent);
- Number of products in defined/planning/estimation stages (35 percent);
- Average project return on investment or average projects payback (31 percent); and
- Percentage increase/decrease in R&D headcount (31 percent).[12]

(Source: Goldense Group Inc., based on 2008 Product Development Metrics Survey)[13]

Artz et al(2000)[14] clarified that a firms' R&D spending is a very good predictor of patent and new product announcements. R&D spending is positively related to patent. However, there could be decreasing returns on R&D spending and patenting.[14] Innovativeness can be measured by patent count with the limitation that all innovations cannot be patented. Inventions which are considered not useful or possible by the USPTO for example perpetual motion machines; or offensive to public morality cannot be patented. Besides, in case of sequential and complementary innovation, patent does not help society or sometimes for the inventor as well. [10]

Different types of collaboration impact R&D cooperation in a different way based on the knowledge flow and firms' innovative decision. Collaboration with research institutes enhances the scope of technological know-how transfer, enriches knowledge pool and enlightens the field of basic research. Partnering with clients and suppliers unveils opportunity to exploit the highly relevant source of external knowledge. Teaming up with vertically related partners in the form of joint venture increases the depth of expertise at the expense greater probability of losing

proprietary knowledge of the firm. It is considered that R&D investment is less with the probability of lower protection to knowledge and less proclivity of knowledge creation.[15]Hence, firms are more inclined to increase their R&D spending where there is greater scope of generating new knowledge and more confident in safeguarding the proprietary knowledge thus created. Increased investment in R&D resulting from collaboration or subsidies (or both) leads to greater innovation output exposed by patent activity. [16]

UNESCO Institute for Statistics measures R&D expenditure from current cost and capital expenditure for R&D performed both internal and external the statistical unit or sector of the economy, the current costs includes labour costs and other current cost for example materials, administrative, labour cost of non-R&D personnel who support R&D perform indirectly. Whereas, capital expenditures focuses on fixed assets used in the R&D programs of statistical unit which is land and building, instruments and equipment, and computer software.[17] Additional concept refer to all expenditure on research and development activities at academics, other institutions, and research institutes.[18]Yet, R&D Expenditure is the fundamental factor to drive an organization outperformed and it can be inferred that the more labour, infrastructure, and asset associated with R&D the organization have, the more R&D expenditure shown. R&D funding resources generated from 3 major sectors: Business Enterprises, Government, Higher education. Over the past decades, the US. has dominated in share of total R&D spending, after the economic recession in US and EU, and the stronger economic of China and India, China tends to spend more on R&D and potentially surpass EU and US in 2018 and 2022 respectively.[19]

In more microperspective, many industries have publicly disclosed their R&D expenditure recently,Some studies find that R&D spending announcement positively affected company's stock value even if the stock value does not directly relate to R&Dperformance. R&D expenditure is one aspect for external monitors to observe and assess the business growth in a long term perspective. Whilst some stakeholder agency theorist argued about hidden agenda in revealing R&D expenditure that the R&D manager may undertake the announcement to promote his or her performance to getting reputation in a field of R&D job market.[20] Boston Consulting Group (BCG) survey 1,500 CEO in global companies about the perspective of R&D spending in the future and 75% of CEO agree with increasing more R&D expenditure should do something with R&D innovation. However, external monitors or investors believe that the more R&D spending, the more competitiveness ability, therefore companies were expected to put more fund in R&D even the sale decreased especially in the high intensity R&D level companies, whereas decreasing R&D expenditure in the low intensive R&D level companies have slightly effect to stakeholders[21] Ralph Gomory, the former IBM Vice president, persisted that no matter sales decrease or increase, a company should invest in R&D in the fixed ratio of sales, not variable ratio.

To analyze the criteria of increasing R&D expenditure, the research explicated about components of R&D expenditure: a firm profitability, a business unit within firms, a concentration of market competitiveness in its industry, a flexibility of funding source, and a type of firm's ownership.[22] The study of Kiyohiko Ito and Vladimir Puik supported some criteria that if the firm size starts to grow by increasing sale growth and employee growth, they will spend more R&D expenditure in term of firm growth, however profit growth has moderate effect to R&D expenditure because it is investment in uncertainty market in the future without knowing payback period[23] and it related to a study which found that spending R&D took several years later to boost sales growth particularly in the high intensity R&D level company, nevertheless other factors were important to increase company performance such as: operational excellence, good company strategic and balanced investment in the future.[24] From the firm growth study,

R&D expenditure acts an important role for creating advanced technology. Study claimed that in the big firms which have sufficient resources, R&D spending draw an opportunity to strength positive effect to innovation and attracting other participants to invest for those advanced technologies [25] The measurement of advanced technologies can be implied to numbers of granted patents Studiesinvestigated top R&D spenders in global companies and their patent output per unit of R&D spending especially in the US.[26]

2.5 R&D Spending and R&D Performance

Expenditure on research and development (R&D) is one of the most widely used measures of innovation inputs. As in innovativeness, R&D performance also can be measured based on two metrics; tangible and intangible.

Table 6: Metrics for R&D Performance Measurement

Metrics	KEY PERFORMANCE INDICATORS
Tangible	Economic Value (Cost Savings/ Revenues) generated by deployment of R&D technologies;
Intangible	Number of Patent Applications; Number of Patent Applications/R&D spending; Number of Publications in international journals; Yearly Technologies/Services transferred to Business Units from R&D;

Intangible value is measured though a number of indicators as follows:

- Number of patent applications – a measure of inventive capability;
- Number of patent applications referred to the overall spending in R&D - a measure of inventive productivity;
- Number of publications in international journals –recognition of R&D achievements at an international level
- R&D Technologies transferred to or adopted by Business Units each year - a measure of R&D capability to respond to business needs.[27]

Tangible value is measured through
R&D intensity – percentage of firm's total investment in R&D compared to revenue[28] because R&D intensity has a positive impact on innovation.[29] Moreover, in many cases R&D intensity is positively related to company reputation. When innovation produces social benefit, it impresses stakeholders and they will perceive this effect and thus have a greater positive effect on the firm's CR.[30]

3. Methodology

Literature review revealed that R&D spending alone cannot warrant innovatiness. But R&Dspending do have impact on R&D performance and is one of the inputs for innovativeness. Hence, in an attempt to clarify how R&D spending is channelized in the top nine Innovative Companies by Booz & Co., a comparative study is done on the number of patent application, number of patent application per unit of R&D spending, R&D Intensity and collaboration. Pearson's *r*(coefficient of correlation) is applied to see if there is measure of the strength of linear dependence between two variables. Correlation coefficient iscalculated by covariance of the two variables divided by the product of their standard deviations.[31]

4. Findings and Analysis

The findings from the analysis of patent number, revenue and R & D expenditure are:

Companies	Number of Patents			Number of Patents to R & D Expenditure (10^{-6})			R & D Intensity (%)		
	'10	'11	'12	'10	'11	'12	'10	'11	'12
Toyota	721	898	1,173	.09	.10	.11	3.5	3.8	4.3
Samsung	5,866	6,148	6,457	.55	.61	.55	5.4	5.4	6.1
GE	1,222	1,444	1,650	.24	.26	.31	7.0	7.2	6.7
IBM	5,866	6,148	6,457	.97	.98	1.02	7.6	7.5	7.5
P & G	332	327	395	.17	.16	.19	6.6	5.2	4.4
Micosoft	3,086	2,309	2,610	.35	.25	.26	6.4	2.5	5.2
Apple	563	676	1,136	.31	.27	.33	6.2	5.8	4.4
Google	275	476	1,151	.07	.09	.10	3.5	4.5	6.0
3M	492	457	391	,08	.07	.06	6.0	5.3	5.4

From the above analysis based on patent number, revenue and R & D expenditure it is found that IBM has the highest inventive capability and also inventive productivity and also in terms of R & D intensity while goolge found to be have least R & D intensity while Toyota shows to have least inventive productivity and P & G has the least inventive capability.

From correlation analysis it is observed that:

1. In the High tech sector (**Google, Samsung, Microsoft, Apple**), there is a very strong correlation between amount spent on R&D and number of Patents filed. In turn, there is a strong correlation between number of patents and net revenue.
2. In Automobile sector (**Toyota**) there is a weaker correlation between amount spent on R&D and number of patents. However if you see the trend on the number of patents it has been filing, trend is on an increase.
3. For **P&G and 3M** there is negative correlation between amounts spend on R&D and number of patents. And even lesser variation in r^2.
4. R&D as a percent of Net Revenue seems to indicate how much value a company put on R&D. Google and Microsoft value R&D the most.
5. There seems to be a medium to strong correlation between average cost per patent and number of patents. IBM has the cheapest patents while Toyota has most expensive patents thereby showing the nature of research in the two different sectors.

5. Conclusion

As revealed from literature review, R&D spending is one of the many pieces in Innovation tapestry. R&D spending was considered to be an input indicator during the first generation for measuring innovativeness. However, recently the approach is more towards adopting intangibles to measure innovativeness. The comparison among various innovation models clarifies that R&D spending is one of the many inputs to innovation. Also, the frameworks emphasize that R&D spending can enhance intellectual capital or knowledge, but there are other capitals in the form of human and organization that can be developed through innovation investment and proper strategy. R&D spending is a part of total innovation investment of a firm. More and more spending on R&D helps companies to improve technological capability but it requires other complementary capability to become innovative. However, as R&D expenditure is one of the most important inputs to innovativeness, analysis of R&D performance in purview of R&D expenditure throughs some light on how the top nine most innovative firms performed in inventive capability, inventive productivity and R&D intensity which can be used as a proxy to corporate reputation.

6.0 Limitation

The study was done with few companies with data for few years. Also the patent citation or number of publications in international journals; yearly technologies/services transferred to Business Units from R&D could not be considered. More advanced quantitative techniques, e.g. quantile regression models could have been applied to have a more reliable outcome from analysis.

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Table 1 : Top 10 Most Innovative companies VS Top 10 Most R&D spend

Rank by year	2010				2011							
	Top 10 MostInnovative		Top 10 R&D Spender		Top 10 MostInnovative		Top 10 R&D Spender		Top 1		0 R&D Spender	
	Company	R&D Spend ($billions)	Company	R&D Spend ($billions)	Company	R&D Spend ($billions)	Company	R&D Spend ($billions)	Comp	any		R&D Spend ($billions)
1	Apple	1.3	Roche	9.1	Apple	1.8	Roche	9.6	Apple			9.9
2	Google	2.8	Microsoft	9.0	Google	3.8	Pfizer	9.4	Googl			9.6
3	3M	1.3	Nokia	8.2	3M	1.4	Novartis	9.1	3M	1.6	Roche	9.4
4	GE	3.3	Toyota	7.8	GE	3.9	Microsoft	8.7	Samsung	9.0	Pfizer	9.1
5	Toyota	7.8	Pfizer	7.7	Micosoft	8.7	Merck	8.6	GE	4.6	Micosoft	9.0
6	Micosoft	9.0	Novartis	7.5	IBM	6.0	Toyota	8.5	Micosoft	9.0	Samsung	9.0
7	P & G	2.0	Johnson&Johnson	7.0	Samsung	7.9	Samsung	7.9	Toyota	9.9	Merck	8.5
8	IBM	5.8	Sanofi-Aventis	6.4	P & G	2.0	Nokia	7.8	P&G	2.0	Intel	8.4
9	Samsung	6.0	GlaxoSmithkline	6.2	Toyota	8.6	GM	7.0	IBM	6.3	GM	8.1
10	Intel	5.7	Samsung	6.0	Facebook	N/A	Johnson&Johnson	6.8	Amazon	2.9	Nokia	7.8

Table 2 : R&D spend by business sectors and mean 2012

Rank 2012	Business Sector											
	Automotive	R&D spd ($ billions)	Computing & electronics	R&D spd ($ billions)	Heavy Industrial	R&D spd ($ billions)	Light Industrials	R&D spd ($ billions)	Consu		Health	R&D spd ($ billions)
1	Toyota	9.9	Samsung	9.0	Siemens	5.1	Dupont	2.0	Nestle		ovartis	9.6
2	Volkswagen	7.7	Intel	8.4	GE	4.6	3M	1.6	P&G	2.0	Roche	9.4
3	Ford	7.3	Nokia	7.8	ABB	1.4			Unilever	1.2	Pfizer	9.1
4	Honda	6.6	Panasonic	6.6					Kimberly cla	0.3	Merck	8.5
5	Daimler	5.8	IBM	6.3							J&J	7.5
	Mean	7.2		7.6		4.85		1.8		1.6		9.0

Table : Net Revenue by company ($ millions)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Toyota	132,620	144,874	161,633	173,379	179,083	202,864	245,693	191,864	203,687	228,247	226,106
Samsung	33,759	36,409	55,256	56,720	91,954	105,018	96,495	119,697	135,771	154,048	187,754
GE	113,856	112,886	123,814	136,262	151,568	172,488	182,515	154,438	149,567	147,288	147,359
IBM	81,186	89,131	96,293	91,134	91,424	98,786	103,630	98,758	106,827	114,440	111,826
P & G	40,240	43,380	51,410	56,740	76,480	78,480	83,500	79,030	78,940	82,560	83,680
Micosoft	28,365	36,840	39,790	44,280	51,120	60,420	58,440	62,480	69,940	74,300	77,310
Apple	5,742	6,207	8,279	13,931	19,315	24,006	32,479	36,537	28,633	41,812	60,949
Google	440	1,465	3,189	4,916	6,138	10,604	16,593	23,650	29,321	37,905	46,039
3M	16,332	18,232	20,011	21,167	22,923	24,462	25,269	23,123	26,662	29,611	29,904

Table : R&D Expenditure by company ($ millions)

Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Toyota	5,508	6,247	6,376	7,057	7,595	8,325	8,962	8,449	7,253	8,695	9,883
Microsoft	6,000	6,400	6,800	6,200	6,500	7,120	8,160	9,010	8,700	9,000	9,800
Samsung	2,500	3,222	4,410	4,950	5,143	4,949	6,390	6,085	8,185	7,955	9,038
Google	8	138	169	599	1,228	2,119	2,793	2,843	3,762	5,162	6,793
IBM	4,750	5,077	5,874	5,842	6,107	6,153	6,337	5,820	6,026	6,258	6,302
GE	2,600	2,656	3,091	3,425	3,659	4,100	4,400	4,400	4,900	5,400	5,200
Apple	446	471	489	534	712	782	1,109	1,333	1,782	2,429	3,381
P&G	1,601	1,665	1,802	1,940	2,075	2,112	2,226	1,864	1,950	2,001	2,029
3M	1,158	1,190	1,246	1,274	1,522	1,368	1,404	1,293	1,434	1,570	1,634

Table : Numbers of patent

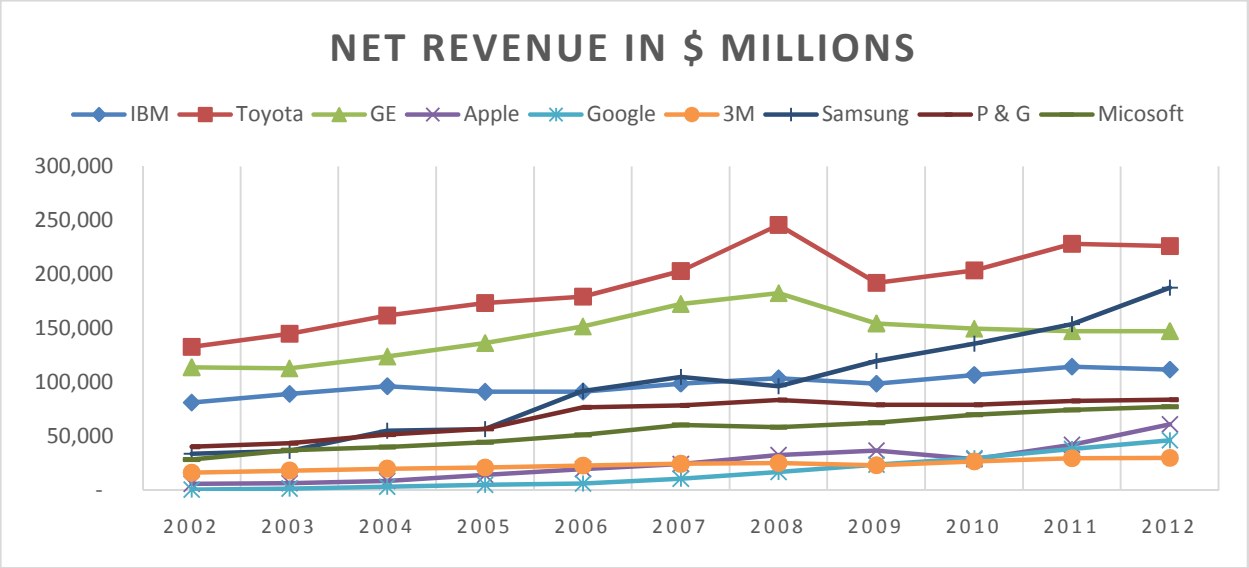
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
IBM	3,288	3,415	3,248	2,941	3,621	3,125	4,169	4,887	5,866	6,148	6,457
Samsung	1,328	1,313	1,604	1,688	2,451	2,723	3,502	3,592	4,518	4,868	5,043
Micosoft	499	499	629	746	1,463	1,637	2,026	2,901	3,086	2,309	2,610
GE	1,416	1,139	976	904	1,051	911	911	976	1,222	1,444	1,650
Toyota	296	273	268	271	384	351	387	453	721	898	1,173
Google	N/A	N/A	N/A	N/A	N/A	N/A	58	141	275	476	1,151
Apple	76	80	94	85	106	118	191	289	563	676	1,136
P & G	433	438	397	296	273	215	208	195	332	327	395
3M	529	572	525	416	471	459	394	322	492	457	391

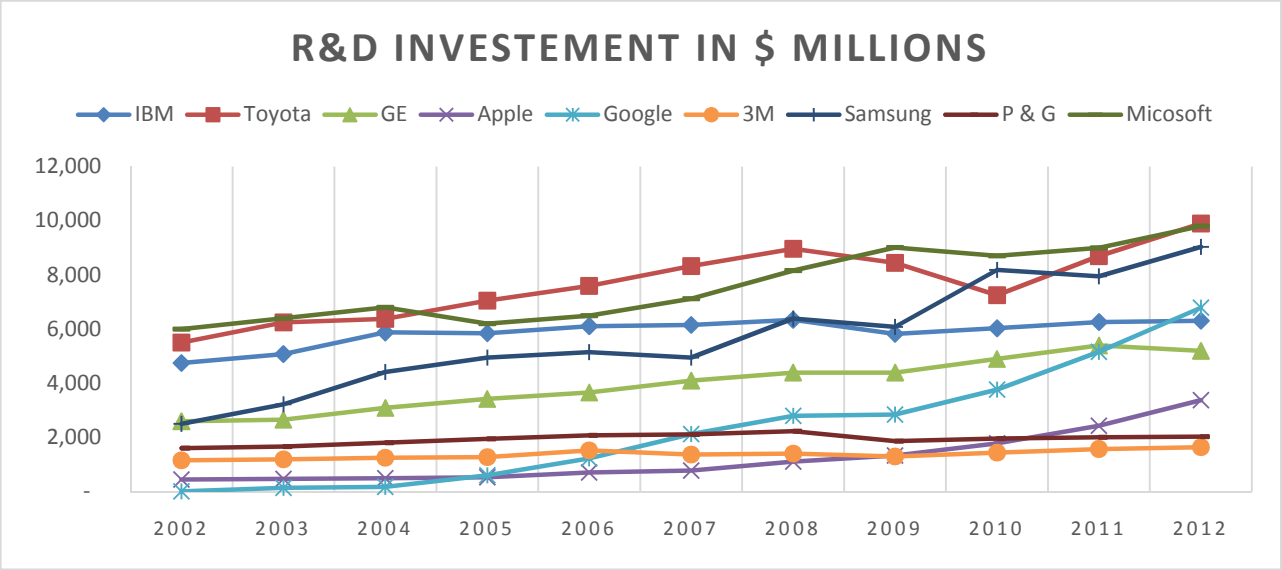
Table : Numbers of employees (consolidated)

Year	2,002	2,003	2,004	2,005	2,006	2,007	2,008	2,009	2,010	2,011	2,012
IBM	315,889	319,273	329,001	329,373	355,766	386,558	398,455	339,409	426,751	433,362	436,426
Toyota	214,631	215,648	246,702	325,029	285,977	299,394	316,121	320,808	320,590	317,716	325,905
GE	315,000	305,000	307,000	316,000	319,000	327,000	323,000	304,000	287,000	301,000	305,000
Apple	12,241	13,566	13,426	16,820	20,186	23,700	35,100	36,800	49,400	62,940	76,100
Google	2,292	2,292	3,021	5,680	10,674	16,805	20,222	19,835	24,400	32,467	53,861
3M	69,720	68,089	68,244	71,227	75,333	76,239	79,183	74,835	80,057	84,198	87,677
Samsung	175,000	198,000	213,000	229,000	254,000	263,000	276,000	276,000	344,000	369,000	395,000
P & G	105,000	105,000	110,000	118,000	126,000	135,000	138,500	137,500	131,000	128,500	127,500
Micosoft	53,000	55,000	57,086	60,000	66,000	79,000	91,000	93,000	91,000	89,500	92,000

Collaboration and Labs

	Lab / RD center	Business Diversify	Academic Collaboration	Government Collab	Company age (years)
Apple	3				37
google	5	x	x	x	15
3M	37	x	x		111
Samsung	24	x	x		44
GE	6	x	x	x	130
Micosoft	13	x	x		38
Toyota	15	x	x	x	75
P & G	26	x	x		176
IBM	12	x	x	x	100


NET REVENUE IN $ MILLIONS
IBM
Toyota
GE
Apple
Google
3M
Samsung
P & G
Micosoft
300,000
250,000
200,000
150,000
100,000
50,000
-
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012


R&D INVESTEMENT IN $ MILLIONS
IBM
Toyota
GE
Apple
Google
3M
Samsung
P & G
Micosoft
12,000
10,000
8,000
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4,000
2,000
-
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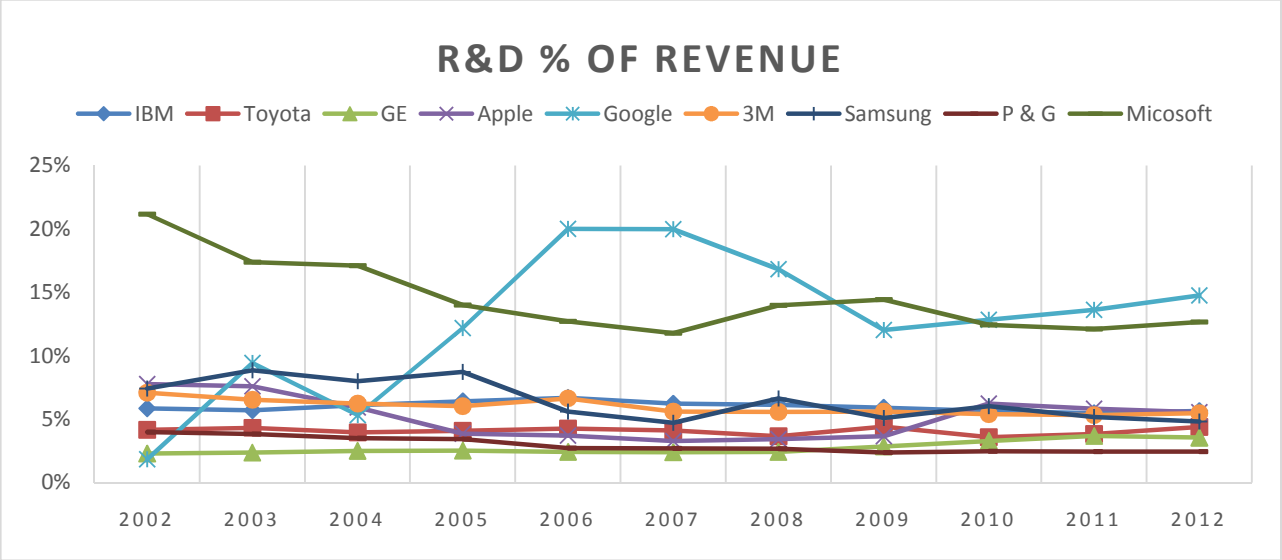
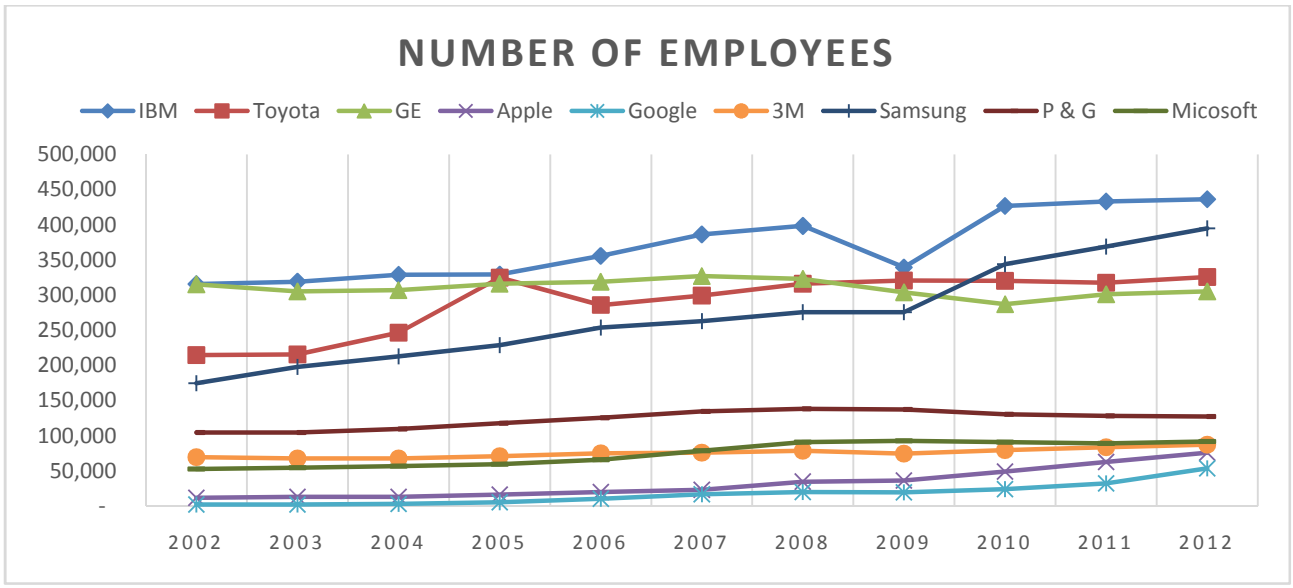
2009
2010
2011
2012


R&D % OF REVENUE
IBM
Toyota
GE
Apple
Google
3M
Samsung
P & G
Micosoft
25%
20%
15%
10%
5%
0%
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012


NUMBER OF EMPLOYEES
IBM
Toyota
GE
Apple
Google
3M
Samsung
P & G
Micosoft
500,000
450,000
400,000
350,000
300,000
250,000
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100,000
50,000
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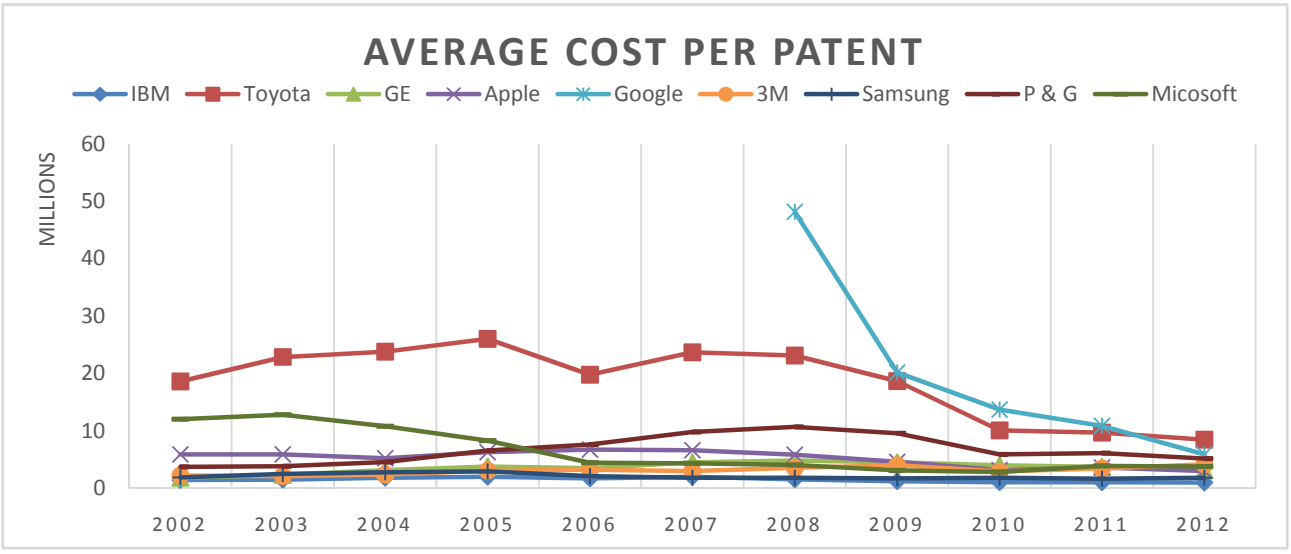
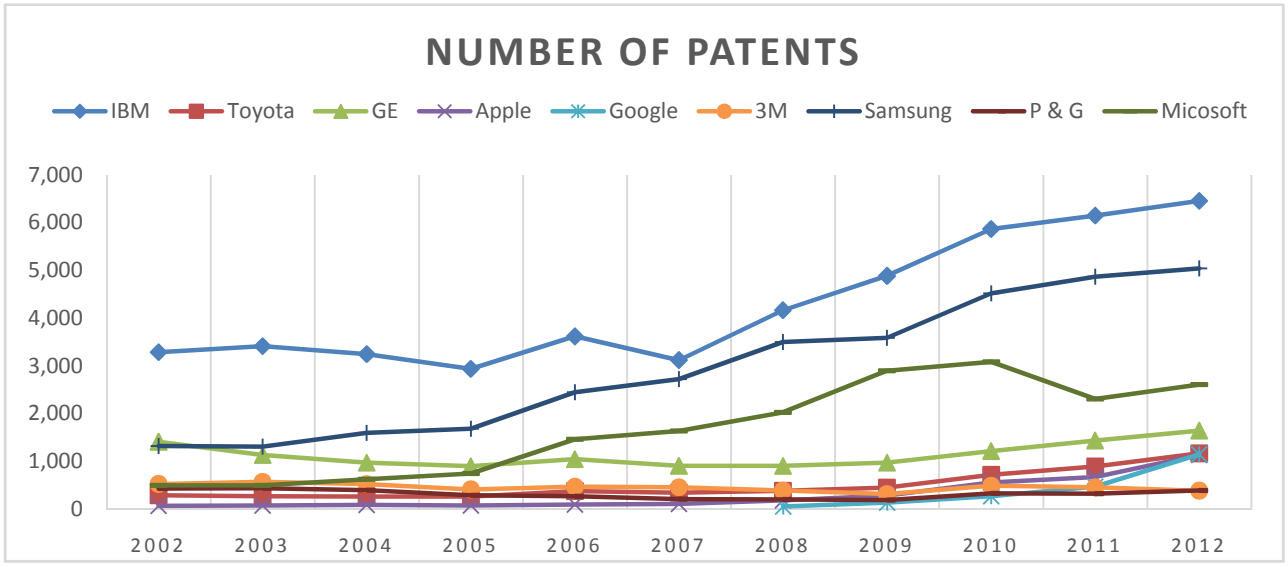
2012


AVERAGE COST PER PATENT
IBM
Toyota
GE
Apple
Google
3M
Samsung
P & G
Micosoft
MILLIONS
60
50
40
30
20
10
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012


NUMBER OF PATENTS
IBM
Toyota
GE
Apple
Google
3M
Samsung
P & G
Micosoft
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

This is a case study analysis where we have chosen top nine most innovative companies according to Booz & Co. out of the 10 most innovative companies which had data for consecutive five years from 2008 – 2012. In qualitative analysis we compared the top 10 most innovative companies based on their R&D spending, Revenue, R&D spending as percentage of revenue, no of patents, cost per patent and number of employees.

In our quantitative analysis, we have used **Pearson's *r*** (coefficient of correlation) to see if there is measure of the strength of linear dependence between two variables. In other words, correlation coefficient between two variables is defined as the covariance of the two variables divided by the product of their standard deviations.[29]

The formula for coefficient of correlation is:

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

Where, X and Y are data from two different variable arrays between which the dependence is being investigated,

$\bar{x}$ and $\bar{y}$ are the mean of the two data sets.

Pearson's coefficient r can vary from -1 to 1.

If r =	
+.70 or higher	Very strong positive relationship between the two variables.
+.40 to +.69	Strong positive relationship
+.30 to +.39	Moderate positive relationship
+.20 to +.29	weak positive relationship
+.01 to +.19	No or negligible relationship
-.01 to -.19	No or negligible relationship
-.20 to -.29	weak negative relationship
-.30 to -.39	Moderate negative relationship
-.40 to -.69	Strong negative relationship
-.70 or higher	Very strong negative relationship

Table 1 : Degree of relationship based on value of r.

The coefficient of determination, r^2, is useful because it gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. It is a measure that allows us to determine how certain one can be in making predictions from a certain model/graph.[30]

4. Key Findings/Analysis:

However, Booz&company criteria might not be strong to justify innovativeness in a long term because limitation of study period which backwards only 3 years. Each business sector has different clockspeed, therefore it cannot conclude the effect of R&D expenditure and innovativeness by Booz only.[28]

Then, we choose data from 9 innovative which has constantly named on the top 10 innovative companies list to analyze other perspectives.

In our analysis, we have tabulated the r for the following three sets of variables.

	Coefficient of correlation (r) between		
Company	**"R&D Expenditure" and "Number of Patents"**	**"Number of Patents" and "Net Revenue"**	**"Avg cost per patents" and "Number of Patents"**
Google	0.971	0.971	-0.918
Samsung	0.963	0.968	-0.922
Microsoft	0.909	0.908	-0.524
Apple	0.988	0.883	-0.880
IBM	0.471	0.847	-0.689
P & G	-0.716	-0.671	-0.914
Toyota	0.626	0.630	-0.595
3M	-0.398	-0.520	-0.977
GE	0.344	-0.314	-0.905

Table 2 :Table of coefficient correlation calculated

Furthermore we have calculated Coefficient of determination (r^2) by squaring the coefficient of correlation.

	Coefficient of determination (r^2) between		
Company	**"R&D Expenditure" and "Number of Patents"**	**"Number of Patents" and "Net Revenue"**	**"Avg cost per patents" vs "Number of Patents"**
Google	0.942	0.942	0.843
Samsung	0.928	0.938	0.850
Microsoft	0.826	0.825	0.274
Apple	0.977	0.779	0.775
IBM	0.222	0.717	0.474
P & G	0.513	0.451	0.836
Toyota	0.392	0.397	0.354
3M	0.158	0.270	0.954
GE	0.118	0.099	0.818