GLOBAL RECESSION IMPACT ON THE MARKET VALUE OF INTANGIBLE ASSETS

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ABSTRACT

Aim of this analysis is to study whether the global recession of 2008 had a significant effect on how stock markets value firms' investments in knowledge and branding as well as complementary investments in patents and trademarks. Building on data from European Intellectual Property Office (EUIPO) and European Patent Office (EPO) we construct a firm panel covering R&D, marketing and IP investments over the period 2005-2012. In addition, we estimate market value equations for the years 2005-2008 and 2009-2012. Empirical findings suggest that there are interesting differences in which investments contributed to market value before and after 2008. First, investments in R&D contribute far more significantly to the market value after the crisis than before. Second, it becomes apparent that after the crisis patent quality arises as a significant factor which increases value of the companies. At the same time patent quantity ceases to be an influencing factor in the market value equation after 2008.

KEYWORDS: Market Value, Tobin's Q, R&D, Patents, Patent Citations, Trademarks, Global Recession

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1. INTRODUCTION

Scholars have always sought to understand how firms extract value from intangible assets. The use of Intellectual Property (IP) has been recognized by industry and academics alike as an important means of appropriating value.

The purpose of this paper is to analyze how stock markets value knowledge assets of the firms in the context of recent economic recession.

The dynamic nature of the global economy has renewed interest in intangible capital and intellectual property as a source of growth for countries and businesses. The recent Great Recession of 2008 has generated uncertainty and resulted in severe restrictions of financial resources for many companies. Firms had to find new ways of allocating resources in a more efficient way. The question how this uncertainty and lack of funds affected innovation strategies in particular, remains little analyzed and deserves more attention to be fully answered.

J. Schumpeter (1942) famously argued that “recessions can provide a platform for innovation and economic growth by unleashing a process of *‘creative destruction’*, i.e. development of new technologies and ways of working”. From this perspective, recession may be seen as an opportunity for companies to exploit the turmoil in the market, overcome competitors, introduce novel products and reform their business models. On the other hand, crisis inevitably impedes the access to financial resources vital to companies’ survival, as well as reduces aggregate demand and consumption; hence the sales of businesses suffer.

The growing importance of intangible assets and the continuing globalization of the world economy up until the financial crisis of 2008 led to world-wide growth in the demand for patent and trade-mark rights. Simultaneously firms’ patenting strategies and their brand building strategies have become increasingly specific to the industry context: for instance firms in the ICT sector increasingly rely on amassing large patent portfolios and producers of consumer goods have extended their core brands to new markets, often creating complex systems of derivative brands.

The focus of this paper is to investigate how the global financial crisis of 2008 affected the interplay of investments in intangibles and investments in the associated IP rights. The level of uncertainty about the depth and duration of this crisis for the world economy was very significant and firms' responses could take two principal forms: i) reduce costs while maintaining their IP portfolios; ii) focus and invest in the most profitable opportunities, while dropping older, less profitable product lines. Either strategy is always prevalent anyway, but both could have become more important to firms during the crisis years.

The paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes data sources and provides the descriptive analysis of estimation sample. Section 4 sets out and explains the empirical model. Section 5 presents and discusses empirical findings. Section 6 concludes. An Appendix provides further analysis and documentation.

2. LITERATURE REVIEW

Most prior research on the market value of intangible assets is concerned with the impact of patent counts and R&D on the valuation of firms by stock markets. This type of methodology was originally introduced by Griliches (1981, 1984). The following decades saw an expansion in the empirical studies examining market value of companies in relation to intangible assets. It is well worth noting that most of the literature is focused on US firms and relies on patent data from United Stated Patents and Trademarks Office (USPTO). The most important studies in this vein were conducted by Griliches (1981, 1984, 1998), Pakes (1985), Jaffe (1986), Conolly and Hirschey (1988), Hall (1993; 2000), Hall et al. (2005), Hall and MacGarvie (2006). The market value of IP for European companies was analyzed by Blundell et al. (1999), Toivanen et al. (2002), Bloom and van Reenen (2002), Greenhalgh and Rogers (2006), Hall and Oriani (2006), Hall et al. (2007). Bosworth and Rogers (2001) conducted similar work for Australia.

Most of these studies relate the stock market value of firms to R&D and patents, as measures of knowledge capital. The typical finding of this work is that R&D has more explanatory power than patent counts in the market value equation. However, patents do contribute to the value of companies and enter the market value equation as a significant factor.

There are fewer empirical studies that incorporate patent citations as a measure of patent quality. Shane (1993) finds that patents weighted by citations have more predictive power that patent counts for a small sample of semiconductor firms. Austin (1993) finds that citation weighted patent counts did not have a significant impact in the biotechnology industry. Hall et al. (2005) were among the first researchers who conducted a large scale study to include a citation-weighted measure of patents in the market value regression. Their findings confirm that patent citations add information above and beyond Research and Development (R&D) and patent counts and help boost the market value of companies.

It is well worth noting that most of the empirical research of the value of IP has been devoted to patents and to a lesser extent - to trademarks. Trademark rights were considered by Sandner and Block (2011), Bosworth and Rogers (2001) as well as Greenhalgh and Rogers (2006) and Thoma (2015). The lack of research on trademarks in the literature evaluating the economic value of intangible assets and in the field of industrial organization in general, was recognized and emphasized by Graham and Somaya (2006), Mendoca et al. (2004) and Sandner and Block (2011).

Comparing the patent and trademark application behavior of firms prior and after the crisis can in turn advance our understanding of the economic value of intangible assets. In order to provide conceptual framework we review the literature which focuses on economic recession impact on innovation.

Several economic studies publish research results with regard to innovation and Intellectual Property during the Great Recession. EUIPO and EPO (2016) suggest that “IPR-intensive industries have proved most resilient to the economic crisis”, as relative contribution of these industries to the EU economy slightly increased between the two periods 2008-2010 and 2011-2013. According to Paunov (2012), one in four firms stopped innovation projects due to the global crisis but innovation performance did not decrease. Her findings are based on firms’ innovation profiles in Latin American countries in 2008-2009. Sumedrea (2013) research confirms the importance of knowledge assets as profitability of companies in crisis time is found to be “linked to the financial capital through the value added intellectual capital coefficient”. Corrado et al. (2016) shed light on the diffusion of intangible investment across Europe and the US over the years 2000-2013. Their estimates suggest intangible investment has been relatively resilient during the Great Recession in 2008-2009, while tangible investment fell massively. Based on Corrado, Hulten and Sichel (2005) methodology they find that intangible investments account for 40% of the capital deepening in the EU and 60% in the US. Cincera et al. (2011) investigate how corporate R&D evolves in the light of the contemporary economic crisis. Albeit company behavior varies, their findings suggest overall positive trend of firms investments in R&D. Some companies inevitably reduced their innovation activities. Companies which maintained the same levels of R&D or increased them were those that "thrive through the downturn and thus seek to gather the benefits in the upswing to come".

To date there is no research which looked at the market response to patent applications or grants in the context of recent Great Recession. This study contributes to the literature by providing novel empirical evidence on the value of R&D investments, patenting and trademarking activities in the context of the recent economic crisis of 2008.

3. DATA

This section discusses in detail the data used for the purposes of this project. We build a comprehensive dataset that brings together accounting, financial market, trademark and patent data. The first sub-section (2.1) clarifies the sources of the data and describes the way they were linked. The second sub-section (2.2) discusses the descriptive statistics.

3.1 DATA SOURCE AND SAMPLE

To perform our empirical study we brought together data from several sources. Data is combined with respect to: i) patents; ii) trademarks; iii) company-level financial data, such as enterprise value and R&D expenditure.

Company characteristics were collected from COR&DIP[1], Bureau van Dijk Amadeus and COMPUSTAT databases. Patent data was obtained from PATSTAT and trademark data was provided by the EUIPO.

We build a novel and rich database[2] linking these accounting and IP datasets via an elaborated matching process. Patents, patent citations and trademarks were consolidated at the corporate level in order to obtain company level IP portfolios.

We sought to obtain accounting and intellectual property data for the most significant R&D investors in the world. The European Commission and the Organization for Economic Co-operation and Development (OECD) provide the COR&DIP database which contains information about the R&D activity and inventive output (i.e. patents and trademarks) of the 2000 top corporate R&D performers worldwide. This data was the starting point of our dataset building process.

The COR&DIP database offers a set of comprehensive and highly useful data. Regarding the purpose of this research it also has several limitations. First, it only contains information for time period 2009-2012. Second, it lacks some information crucial for our empirical analysis, namely, enterprise value, total assets and brand related expenditure. We benefited from the good coverage of R&D expenditure information. Additional information to patent applications, such as grant dates, validation information and citations is also not provided by COR&DIP. In order to obtain additional information and expand the timespan of analysis we engaged in the process of matching the COR&DIP company sample with accounting data from Amadeus and COMPUSTAT. Patent data was linked using PATSTAT and trademark data was obtained from EUIPO.

Explications below outline in more detail the specific datasets with regard to patents, trademarks and financial information of the companies.

Patent data

Patent data was collected from PATSTAT[3] (April 2016 version). We extracted and observed patent application, grant, validation and renewal decisions and dates, as well

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[1] IP bundle of top corporate R&D investors, EC-JRC/OECD COR&DIP© database, v.0. 2015

[2] The detailed description of dataset building process is available in the Annex A.

as the citations to applied and granted patents over the period 1978-2014. The payment dates of the validation and renewal fees have been used as indicators identifying the life cycle of each patent.

Trademark data

Trademark data was provided by EUIPO[4]. This data source collects information on the universe of European trademark applications, trademark renewals, cancellations, expirations and NICE classes[5] of the applications over the period 1996-2014.

Company level financial data

Company-level financial data is extracted from three data sources: COR&DIP, Bureau van Dijk Amadeus[6] and COMPUSTAT[7]. The main source of the company information is constituted by the EC-JRC (European Commission Joint Research Centre) and OECD (Organization for Economic Co-operation and Development) joint project "World Corporate Top R&D Investors: Innovation and IP bundles". The COR&DIP database provides a list of the top 2,000 corporate R&D performers worldwide. It contains information about the R&D activity and inventive output (i.e. patents and trademarks) of these 2000 companies[8]. The database also allocates each

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[3] PATSTAT contains bibliographical and legal status patent data extracted from the EPO (European Patent Office) databases and is provided as raw data or online.

[4] The European Union Intellectual Property Office (EUIPO), which was known as OHIM until 23 March 2016, is a decentralized agency of the European Union to offer IP rights protection to businesses and innovators across the European Union (EU) and beyond.

[5] The Nice Classification, established by the Nice Agreement (1957), is a system of classifying goods and services for the purpose of registering trademarks.

[6] Bureau van Dijk is a Moody's Analytics Company. Its dataset Amadeus contains information on around 21 million companies across Europe: https://amadeus.bvdinfo.com.

[7] Standard & Poor's COMPUSTAT is a database of financial, statistical and market information on active and inactive global companies throughout the world:
https://www.spglobal.com/marketintelligence/en/?product=compustat-research-insight

[8] The IP bundle of top corporate R&D investors database (EC-JRC/OECD COR&DIP) results out of the collaboration between the EC-JRC Institute for Prospective Technological Studies (IPTS) and the OECD Directorate for Science, Technology and Innovation (STI). Information about the R&D investors is taken

firm to an ICB (Industry Classification Benchmark) sector code, on the basis of its dominant activities. In addition COR&DIP lists Research and Development (R&D) investment, Net sales, Capital expenditure, Operating profits and Number of employees over the period 2009-2012.

Bureau van Dijk Amadeus database contains accounting data of the European firms. COMPUSTAT dataset provides with the accounting information of non-European companies, most of which are USA, Canadian and Japanese companies. We use the indicators of Enterprise value, Total Assets, Intangible Assets, R&D expenditure, Operating expenditure, Employment, Net Sales provided by Amadeus and COMPUSTAT for the period 2000-2014.

Constructing the dataset

A number of matching and data cleaning exercises were carried out in order to create the final dataset for the empirical analysis. The matching of five datasets proved to be a large scale and challenging task. A great deal of our efforts was devoted into ensuring the links are correct and the fullest set of information is retrieved.

COR&DIP dataset was a starting point of our analysis. We relied on information of the top 2000 R&D intensive companies[9]. This information contains company characteristics, their patent applications at the EPO as well as trademark applications made at the EUIPO during 2010-2012. A significant benefit of the COR&DIP dataset is that it contains harmonized company names for the corporate top 2000 R&D investors worldwide. It also links IP data to enterprise data using the names of the companies and of their subsidiaries (as of 2012) and matches those to applicant names provided in

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from the 2013 EU Industrial R&D Investment Scoreboard. Intellectual property (IP) – related information is taken from EPO's Worldwide Patent Statistical Database (PATSTAT, Autumn 2014) database for patents and from selected IP offices in the case of trademarks: 1) Patent applications filed at the five top IP offices (IP5) in the world, namely: EPO (European Patent Office), JPO (Japan Patent Office), KIPO (Korean Intellectual Property Office), SIPO (State Intellectual Property Office of the People's Republic of China), and USPTO (United States Patent and Trademark Office); 2) Trademark applications filed at the USPTO, OHIM (Office for Harmonization in the Internal Market) and IP AUS (IP Australia).

[9] Information about the R&D investors is taken from the 2013 EU Industrial R&D Investment Scoreboard.

patent and trademark documents[10]. COR&DIP dataset already provides with the information on patent and trademark portfolios for the top R&D investing firms for the period 2010-2012. However, in order to carry out our study a longer time period was required as the aim of this paper is to observe whether global financial crisis of 2008 had a significant effect on how markets value firms' investments in knowledge as well as investments in patents and trademarks.

We were able to complement the COR&DIP dataset substantially by linking in additional information from PATSTAT and EUIPO. Linking these data together yielded a total of 1.709 companies represented in 44 different countries. Final dataset for IP rights allows identifying EPO patent information over the period 1978-2015[11]. In addition, we collected the data for trademark application filings over the period 1996-2014[12]. Accounting information, including enterprise value of the company, R&D expenditure, total assets, marketing expenditure, turnover and employment is available for years 2000-2014. It is well worth recognizing that for a fraction of initial 2000 companies sample, i.e. the 291 companies were not matched with accounting and IP data due to limitations in accounting data availability and possible company name incoherence. It is also important to stress that company names are observed as provided by COR&DIP. Company names and their ownership situation is observed as in year 2013. The process of matching applicants to corporate entities is outlined in Appendix A.

In the course of constructing the estimation sample further data availability restrictions were imposed. First, only companies with data for R&D expenditure and operating expenditure available at least since 2003 were considered in the regressions. This restriction resulted in the sample of 578 firms. In addition, companies with missing enterprise value and other regression variables were eliminated from the estimations. Hence the final estimation sample comprises a total of 481 companies. They are

[10] The linking was carried out on a by-country basis using a series of algorithm contained in the Imalinker system (Idener Multi Algorithm Linker) developed by the OECD by IDENER, Seville, 2013 (Dernis et al., 2015).

[11] 1978 marks the establishment of European Patent Office.

[12] 1996 marks the beginning of European Union IP Office activity (then OHIM – Office for Harmonization in the Internal Market).

allocated in 10 different jurisdictions: Belgium, Canada, Switzerland, Curacao, Germany, France, Israel, Netherlands, Singapore and the United States of America. Most of these companies (357) originate from the USA. 108 firms are headquartered in Europe. With regard to geographical allocation our sample is unbalanced.

In the following sub-section we discuss in more detail the sample characteristics and engage in descriptive statistical analysis.

3.2 DESCRIPTIVE STATISTICS

This section provides descriptive analysis of the estimation sample. We focus on characteristics of 481 companies represented over 10 jurisdictions and 15 industry groups. Table 1 below shows the summary statistics for the estimation sample.

The estimation sample is composed of the companies that are ranked among the 2000 most R&D investing companies in the world. Hence the estimation sample of this study is biased in this sense. The results must be considered taking the sample qualities and bias into account. The average market value of companies in the regression sample is 13 billion euros. On average these firms spend 357 million euros per year on R&D, own around 391 patents and 70 trademarks. Over the period 2005-2012, these companies tend to apply for 92 patents at the EPO, and file 7 new trademark applications at the EUIPO on a yearly basis.

Descriptive statistics indicate that market value as well as various knowledge stocks[13]: R&D, patents, citations and trademarks, are highly skewed, with the means of these variables far exceeding the median.

Ratios of Tobin's Q[14], R&D/Assets, Citations/Patents or OPEX/Assets demonstrate more symmetric distribution as reflecting the systematic size effects. Patents/R&D ratios however are relatively highly skewed with standard deviation over 1.2. High variation in Patent counts to R&D ratio is expected. Even though patents are largely considered to be an indicator of R&D "success", patent counts are also extremely

[13] Detailed explications of all variables and their computations are provided is section 3.2.

[14] Tobin's Q is the ratio between Market Value and Total Assets of the company. Explication is provided is section 3.2.

noisy indicator of return on R&D investments (Hall et al., 2005). The usefulness of patent counts measure is diminished by large variance in the value of patents themselves. This study seeks to analyze whether patent citations, as a proxy for the patent quality, might convey additional information and serve as a significant factor in the market value regressions.

Table 1: Descriptive Statistics

Variables	Mean	Median	SD	Min	Max
Market value, mln EUR	13.000	2.337	31.682	-143	388.596
Total Assets, mln EUR	12.125	2.033	35.299	4	580.072
R&D, mln EUR	357	62	907	0	7.891
R&D stock, mln EUR	1.269	218	3.307	4	32.910
Operating expenditure, mln EUR	5.303	1.041	16.100	6	274.773
Operating expenditure stock, mln EUR	25.854	4.649	79.638	28	1.296.558
Patent applications	92	12	262	0	3.782
Patent applications stock	494	51	1.401	0	19.495
Patent portfolio	391	33	1.020	0	13.199
Citations to applications	111	11	378	0	9.493
Citations to applications stock	595	59	1.688	0	20.495
Citations to grants	38	3	111	0	1.848
Citations to grants stock	259	29	675	0	5.350
Trademark applications	7	1	15	0	206
Trademark portfolio	70	14	148	0	1.922
Regression variables	**Mean**	**Median**	**SD**	**Min**	**Max**
TQ	1,633	1,224	1,653	-0,380	38,925
R&D/Assets	0,216	0,126	0,289	0,002	3,695
Patent portfolio/R&D*1000	0,509	0,162	1,253	0,000	26,375
Patent applications/R&D*1000	0,615	0,240	1,265	0,000	19,804
Citations/Grants	1,305	0,583	3,180	0,000	65,690
Citations/Applications	1,354	0,929	1,455	0,000	15,263
Opex/Assets	2,775	2,271	2,063	0,168	20,934
Trademarks/Assets*1000	0,014	0,005	0,030	0,000	0,484
Observations	3.235				
Firms	481				

Note Table1: N = 3,235 observations for 481 firms. Values are provided for the estimation sample, taking into account period 2005-2012.

The mean value of Tobin's Q (TQ) is 1.6. This is a high value. In the equilibrium Tobin's Q is expected to be at unity, indicating parity between book value of the company and that of the stock market. TQs' positive deviation from unity suggests that the market values company above the value of its assets reported in the balance sheet. Knowledge assets are among the unrecorded factors that are expected to contribute to such positive market evaluation. As emphasized by Hall (2000), market value is a useful measure for innovation if we can rely on the fact that companies are bundles of assets, both tangible and intangible. Value of these assets is determined by the financial markets. In that sense, pricing of the companies are comparable to pricing of other goods in the market, and hedonic price models can be applied.

Table 2: Descriptive Statistics, Pre-crisis and Post-crisis periods

	Pre-Crisis: 2005-2008			**Post-Crisis: 2009-2012**		
Variables	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
Market value, mln EUR	12.754	2.111	31.992	13.203	2.530	31.432
Total Assets, mln EUR	10.977	1.874	33.187	13.074	2.222	36.934
R&D, mln EUR	229	34	628	462	88	1.073
R&D stock, mln EUR	887	144	2.373	1.585	281	3.887
Operating expenditure, mln EUR	5.003	952	15.771	5.552	1.109	16.369
Operating expenditure stock, mln EUR	22.577	3.866	70.774	28.559	5.442	86.198
Patent applications	102	12	289	83	12	238
Patent applications stock	506	45	1.425	484	57	1.380
Patent portfolio	439	35	1.124	353	32	923
Citations to applications	119	12	341	105	10	407
Citations to applications stock	593	55	1.615	597	61	1.746
Citations to grants	47	5	126	30	2	97
Citations to grants stock	280	30	706	242	26	648
Trademark applications	6	1	15	7	1	16
Trademark portfolio	59	11	124	79	17	166
Regression Variables	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
TQ	1,703	1,239	1,901	1,575	1,206	1,414
R&D/Assets	0,144	0,089	0,175	0,276	0,172	0,345
Patent portfolio/R&D*1000	0,762	0,266	1,721	0,300	0,101	0,572
Patent applications/R&D*1000	0,865	0,344	1,709	0,408	0,188	0,645
Citations/Grants	1,252	0,561	3,008	1,349	0,603	3,316
Citations/Applications	1,404	0,924	1,654	1,313	0,934	1,265
Opex/Assets	2,570	2,110	1,932	2,945	2,444	2,151
Trademarks/Assets*1000	0,013	0,004	0,026	0,015	0,005	0,033
Observations		1.463			1.772	
Firms		445			477	

Note Table 2: Values are provided for the estimation sample. N=1463 observations during pre-crisis period, 2005-2008. N=1772 observations during post-crisis period, 2009-2012.

Further empirical analysis of this study seeks to disentangle the components contributing to the market value of a company by measuring the effects of R&D, patents, patent citations and trademarks to the Tobin's Q ratio.

Table 2 summarizes descriptive statistics of the main variables while splitting the time period into two parts[15]. The first time period encompasses pre-crisis years 2005-2008. The second time period encompasses post-crisis years 2009-2012.

The main difference that emerges between these two periods is the slight reduction in Tobin's Q ratio, falling from 1.7 to 1.57. It indicates that on average the book value of these companies increased at a faster pace compared to its value reflected in financial markets. Companies in the estimation sample heavily increase their R&D expenditure. R&D to Assets ratio also shifts from 0.14 to 0.27 between the two periods. At the same time, operating expenditure (OPEX) to Assets ratio increases only marginally.

Patents/R&D ratio exposed much less within-variation in the post-crisis period, reflected in the reduction of standard deviation and a smaller difference between mean and the median. The average patent portfolio of estimation sample reduced to 353 patents in 2008-2012 compared to 439 patents during 2005-2008. Accordingly, the mean of new patent applications filed on yearly basis reduced to 83 from 102. Mean of trademark applications increased up to 7 from 6, however.

Table 3 shows industry differences for selected variables. The sample comprises 15 industry groups as classified by ICB (Industry Classification Benchmark), on the basis of the super-sector. In total there are 19 super-sectors in the ICB taxonomy. The estimation sample is composed of the companies that represent quite a wide span of different industries. Most of the observations represent Technology industry group which is composed of Software and Computer services and Technology Hardware and Equipment. 140 companies of the estimation sample operate in this field. 114 firms represent Health Care industry, which is composed of Health Care Equipment & Services and Biotechnology & Pharmaceutical sectors. Third largest industry group of

[15] The t-tests were run in order to test whether the differences between pre-crisis and post-crisis periods are significant. They confirm significant difference between the means of the most of variables reported in Table 2. The t-test results are reported in Table 20 in the Appendix E.

the estimation sample is Industrial goods and services. Companies operating in the Aerospace & Defense, Electronic & Electrical Equipment and Industrial Engineering fall under this category. Tobin's Q differs quite significantly across the industry groups. The highest TQ value is observed in Health Care as well as Food & Drug Retailers (Retail super-sector). Companies in Financial Services also have a high Tobin's Q value. This is explained by considerably lower assets in comparison to the market value of the companies in this industry. Lowest values of Tobin's Q occur in the industry of Basic Resources, composed of Forestry & Paper, Industrial Metals & Mining and Mining sectors. Contrary to Financial Services, companies that operate in this industry tend to have relatively high value of total assets, which drives down the TQ ratio to market value. Same applies to Automobiles & Parts and Telecommunications industries.

Table 3: Industry characteristics

Industry name	**N**	**Perc.**	**Firms**	**TQ**	**R&D/ Assets**	**Patent portfolio/ R&D *1000**	**Citations/ Grants**	**Opex/ Assets**	**TM/ Assets *1000**
Technology	900	27,8%	140	1,61	0,28	0,27	0,84	2,88	0,010
Health Care	769	23,8%	114	2,54	0,35	0,45	2,88	2,04	0,021
Industrial Goods & Services	768	23,7%	111	1,26	0,12	0,60	0,79	2,98	0,010
Chemicals	277	8,6%	39	1,09	0,09	1,03	0,84	2,72	0,014
Automobiles & Parts	143	4,4%	21	0,70	0,19	0,41	0,85	4,60	0,004
Personal & Household Goods	135	4,2%	20	1,24	0,11	1,11	0,82	3,81	0,035
Oil & Gas	58	1,8%	8	1,20	0,03	0,28	0,72	2,73	0,002
Food & Beverage	51	1,6%	7	1,46	0,05	0,18	1,23	2,73	0,011
Construction & Materials	34	1,1%	6	0,64	0,04	0,13	0,46	2,04	0,003
Media	30	0,9%	4	2,16	0,17	1,09	0,83	2,35	0,014
Basic Resources	22	0,7%	3	0,61	0,02	0,42	0,38	2,67	0,000
Retail	16	0,5%	3	3,02	0,10	0,00	0,66	3,64	0,003
Utilities	15	0,5%	2	1,54	0,02	1,22	0,54	0,49	0,001
Telecommunications	10	0,3%	2	0,80	0,06	0,28	0,18	1,40	0,002
Financial Services	7	0,2%	1	3,36	0,44	1,76	0,41	2,54	0,376
Total	3.235	100,0%	481						
Mean				1,63	0,22	0,51	1,31	2,78	0,014

Note Table 3: N = 3,235 observations. Values are provided for all companies in the regression sample. Company data is provided as yearly averages, taking into account period 2005-2012.

Table 4 displays country differences for selected variables. Nearly 70% of companies in the estimation sample are headquartered in the USA. 108 are European companies. At this point it is important to stress that companies in our sample tend to operate on the multinational level in spite of their origin. Tobin's Q and other variables do not convey much information based on the geographical categorization alone.

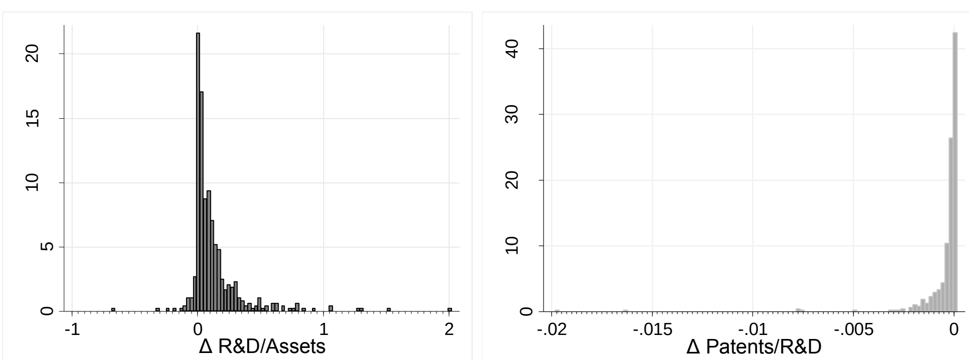
Table 4: Country characteristics

Country	N	Perc.	Firms	TQ	R&D/ Assets	Patent portfolio/ R&D *1000	Citations/ Grants	Opex/ Assets	TM/ Assets *1000
USA	2.351	72,7%	357	1,76	0,23	0,46	1,51	3,27	0,014
France	271	8,4%	36	0,93	0,13	0,52	0,71	1,22	0,006
Germany	246	7,6%	33	0,94	0,19	0,79	0,60	1,07	0,019
Switzerland	204	6,3%	29	2,06	0,25	0,66	0,78	1,59	0,011
Canada	62	1,9%	10	2,23	0,32	0,75	1,18	2,92	0,021
Nerherlands	46	1,4%	8	0,95	0,19	0,40	1,04	0,78	0,007
Israel	26	0,8%	4	0,94	0,18	0,22	1,32	2,47	0,054
Belgium	14	0,4%	2	0,69	0,12	1,03	0,54	0,50	0,005
Singapore	8	0,2%	1	0,57	0,37	0,20	0,27	9,97	0,000
Curaçao	7	0,2%	1	2,39	0,04	0,93	0,50	2,04	0,001
Total	3.235	100,0%	481						
Mean				1,63	0,22	0,51	1,31	2,78	0,014

Note Table 4: N = 3,235 observations. Values are provided for all companies in the regression sample. Company data is provided as yearly averages, taking into account period 2005-2012.

Figure 1 shows that companies are differently distributed regarding the post-crisis change in R&D to Assets ratio and that of Patents to R&D. Right skewed distribution of R&D/Assets ratio change between post-crisis and pre-crisis period shows that most of the companies tended to increase R&D to Assets in the post-crisis period. An opposite pattern is observed in the change of Patents to R&D ratio. Majority of companies decreased Patents/R&D ratio in the post-crisis. The change can be perceived as marginal, as nearly all sample falls under the range -0.005 and 0. Nevertheless, a clear pattern is observed.

Figure 1: Firm distribution



Note Figure 1: Distribution of 481 companies in the estimation sample is depicted. Left-hand side shows firm distribution by average post-crisis (2009-2012) and pre-crisis (2005-2008) difference in R&D stock/Assets ratio. Right-hand side graph shows firm distribution by average Patent portfolio/R&D stock ratio difference between post-crisis (2009-2012) and pre-crisis (2005-2008).

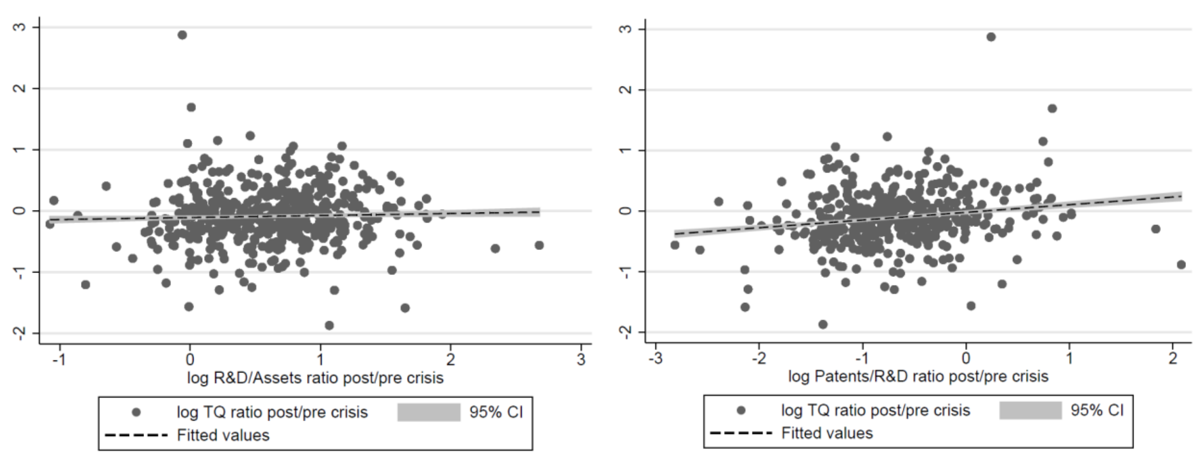
Table 5 groups companies according to their behavior after the crisis, during 2009-2012, compared to pre-crisis period over 2005-2012 As figure 2 also demonstrates, most of the companies increase their R&D to Assets ratio and decrease Patents to R&D ratio after 2008. This pattern of behavior applies to 379 companies out of total 481 in the sample.

Table 5: Firm allocation by change in the Post-crisis period

		Δ Patents/R&D		
		decrease after 2008	increase after 2008	**Total**
Δ R&D/ Assets	decrease after 2008	37	14	**51**
	increase after 2008	379	51	**430**
	Total	**416**	**65**	**481**

Note Table 5: Estimation sample of 481 firms is observed. We measure average differences between post-crisis (2009-2012) and pre-crisis (2005-2008) period for Patent portfolio/R&D stock and R&D stock/Assets.

Figure 2: Correlation: Tobin's Q, R&D/Assets and Patents/R&D



Note: Figure 2 takes into account 481 companies of the estimation sample. The left-hand side graph shows the relationship between post-crisis and pre-crisis ratio in Tobin's Q and in R&D stock/Assets ratio. The right-hand side graph shows the two-way relationship between post-crisis and pre-crisis ratio in Tobin's Q and in the Patent portfolio/R&D stock ratio.

It is interesting to observe whether change in R&D/Assets and Patents/R&D was associated with certain change in market value for these companies. Figure 2 illustrates the pre-crisis Tobin’s Q relative to post crisis Tobin’s Q relationship with the post crisis and pre-crisis ratios of these variables. A positive association is observed between the growth in R&D stock and growth in market value in the post-crisis period compared to pre-crisis period. It is sustained by the following regression analysis conducted in section 4. Patents/R&D ratio growth after the crisis is also positively and significantly related with Tobin’s Q growth. The same relationship does not hold in the empirical model estimations when additional controlling variables are included.

The following section outlines the empirical model applied in estimating the market value equations. It also discusses the regression variables in the explicit manner.

4. EMPIRICAL MODEL

This section outlines the Market Value equation specification and discusses the empirical model.

4.1 FIRM LEVEL MARKET VALUE

Firm level analysis is conducted. The aim of this study is to assess how market value is affected by the investments in knowledge stock and investments in Intellectual Property (IP). We also aim to assess whether these effects differed in the period before the crisis, during 2005-2008, and after the crisis, during 2009-2012.

The majority of studies on innovation and performance use market valuation as an indicator of the expected value of future profits of the firm. There are two measures of a company’s market value: market capitalization and enterprise value. The latter is a more precise measure. Market capitalization is calculated by multiplying current stock price and number of shares outstanding. While it provides information about company’s size, its real share value and expected risk, it omits important factors in the overall valuation of a firm. Enterprise value takes into consideration the value of the debt obligations as well as cash and cash equivalents in addition to equity value. In general, enterprise value indicates real price that the company could be bought for in the current market.

We posit a firm's market value equation in which market value (MV) is a function of total assets *(A)*, investments in R&D *(R)* and branding *(B)*, stocks of patents *(P)* and trademarks *(T)* as well as a random i.i.d. error term *(ϵ)*:

$$MV_t = (A_t, R_t, B_t, P_t, C_t\ T_t, \in_t) \tag{1}$$

Firm level market value equation was first introduced by Griliches (1981, 1984). This approach has been widely applied in econometric studies by Blundell et al. (1999), Hall et al. (2005, 2007), Gambardella et al. (2008), Thoma (2015) and others. The firm's market valuation is given by Tobin's Q equation. In its most general form the model takes form of the Cobb-Douglas function:

$$V_{it}(A, K) = q_t\ A_{it}^{\alpha}\ K_{it}^{\beta} \tag{2}$$

Typical Tobin's Q model starts with the assumption that company is composed of two types of assets. Tangible assets *(A)* and knowledge stock (*K*) contribute to the value of the company (V_{it}). A_{it} denotes the book value of companies' total assets at time *t*. K_{it} denotes the knowledge stock of the firm at a time *t*. q_t is the marginal Tobin's q. It can be interpreted as the average market valuation coefficient of firm's total assets, reflecting its differential risk and monopoly position.

Expression 2 can be understood as a model that is known in literature as a hedonic pricing model, where the good being priced is the firm and the characteristics of the good are its assets, both tangible and intangible (Hall and Oriani, 2006).

Typically, in market value estimation models, constant returns to scale are assumed. Therefore, $\alpha + \beta = 1$ in equation 2. In logarithms, equation 2 can be transformed as following:

$$\log V_{it} = \log q_t + \alpha \log A_{it} + \beta \log K_{it} \tag{3}$$

Given the constant returns to scale, equation 2 also takes the following form:

$$\log\frac{V_{it}}{A_{it}} = \log q_t + (\alpha - 1)\log A_{it} + \beta\log\frac{K_{it}}{A_{it}} \quad (4)$$

The dependent variable of the equation 4 represents Tobin's Q (TQ). Tobin's Q is the ratio of market value to the total assets reported by the firm. It also defines the replacement cost of the company (Hall et al., 2007). Under perfect competition TQ ratio is expected to be equal to unity. Tobin's Q deviation from unity is considered to be driven by unrecorded assets, such as knowledge assets or intellectual property, which positively contributes to companies' value premium. Firms with high level of intangible knowledge capital have a higher market value than one might expect in case only physical assets were taken into account (Bloom and van Reenen, 2002).

Various authors choose different measure to account for the knowledge assets. In general, most of the studies rely either on the R&D expenditure of the firm, or the counts of the patents or trademarks in order to approximate for the intangible assets. Our empirical model is described below. For the empirical analysis the equation 4 is rearranged in the following form:

$$\ln Q_{it} = \ln\frac{V_{it}}{A_{it}} =$$
$$\ln q_{it} + \beta_1 \ln A_{it} + \beta_2 \ln\frac{R_{it}}{A_{it}} + \beta_3 \ln\frac{PT_{it}}{R_{it}} + \beta_4 \ln\frac{C_{it}}{PT_{it}} + \beta_5 \ln\frac{B_{it}}{A_{it}} + +\beta_6 \ln\frac{TM_{it}}{A_{it}} + \delta_i + \tau_t + \varepsilon_{it} \quad (5)$$

The firm level market value equation 5 is estimated by ordinary least squares (OLS). It is regressed over the period 2005-2012, and additionally over the pre-crisis period of 2005-2008, and post-crisis period of 2009-2012. Firm specific time invariant effects (δ_i), time effects (τ_t) and a random stochastic term (ε_{it}) are taken into the account. In particular, firm valuation is regressed against several characteristics of firm's intangible assets including R&D investment, operating expenditures, as well as stocks of patents and trademarks. Measure of citations to patents is used as a proxy to capture the quality of the patents. The intercept *($\ln q_{it}$)* represents the average logarithm of Tobin's q for the sample firms. It captures the adjustment of the overall macro-economic effects in the stock market and can be interpreted as an estimate of the logarithmic average of Tobin’s Q for the sample of firms during the relevant period (Hall, 2000). The meaning of the regression variables is described in more detail in the following sub-section.

4.2 COVARIATES

The meaning of the variables in the estimating equation 5 is described as follows.

Tobin's Q, (Q) or (V/A) – This is the dependent variable. Tobin’s Q equals to the ratio of the firm's market value to its total assets. Market value of the company takes into consideration equity value of the company in addition to the value of the debt obligations as well as cash and cash equivalents. It is based on Bureau van Dijk and COMPUSTAT “Enterprise Value” measurement. Tobin’s Q can be interpreted as a premium of companies’ value which is generated by unrecorded assets. Our regression analysis seeks to disentangle components contributing to this premium.

Total assets (A) – annual book value of the total (tangible and intangible) assets of the company.

R&D stock (R) – the stock of past R&D investment. The stock is constructed as cumulative sum. We apply 15% annual depreciation rate[16] to the R&D stock.

$$\mathrm{RD}_{\mathrm{t}}^{\mathrm{stock}} = \mathrm{RD}_{\mathrm{t}}^{\mathrm{flow}} + (1-\delta)\mathrm{RD}_{\mathrm{t-1}}^{\mathrm{stock}} \tag{6}$$

Here $\delta = 15\%$ annual depreciation rate. It is usually assumed to be 15% (Hall et al., 2005; Thoma, 2015). In the model estimations R&D stock is scaled to total assets: (R/A).

Operating expenditure stock (B) – this is the stock of past operating expenditure (OPEX). We rely on the book value of the operating expenditure of the company as a

[16] 15% depreciation rate was suggested and first introduced by Hall B.

proxy indicator for the advertising expenditure. It is scaled to total assets in the regressions, similarly to R&D: (B/A).

$$B_t^{stock} = B_t^{flow} + (1 - \delta)B_{t-1}^{stock} \quad (7)$$

Here $\delta = 15\%$ annual depreciation rate. The stock is constructed as cumulative sum and declining balance formula is applied.

Patent Portfolio (PT) – this is the size of each firm's overall valid patent portfolio. In the model estimation we include patent portfolio ratio to R&D expenditure stock. Patents can be considered as the output of R&D (Hall et al., 2005; Thoma, 2015). Hence, patents/R&D ratio can interpreted as patent productivity. Notification in the estimation equation 5: (PT/R).

$$PT_t = PT_{t-1} + p_t - \bar{p}_t \quad (8)$$

Here PT_{t-1} is the past total stock of valid patents[17] (i.e. patents that are granted by the EPO and subsequently validated). p_t is the inflow of validated patents in the current year; $\bar{p}_t$ is the outflow of patents in the current year: patents that lapsed (i.e. validation fees or renewal fees were stopped being paid by companies), or patent exceeded its maximum lifetime of 20 years and fell in the public domain.

Patent Application Stock (APT) – the past stock of patent applications filed at the EPO at any time over the period 1978-2012. Application stock ratio to R&D expenditure stock is included in the regressions. Notification in the estimation equation 5: (PT/R).

$$APT_t^{stock} = APT_t^{flow} + (1 - \delta)\, APT_{t-1}^{stock} \quad (9)$$

Here $\delta = 15\%$ annual depreciation rate. Similarly to R&D and operating expenditure stock, patent applications are assumed to lose a fraction of their value every year. Such

[17] Number of validation jurisdictions is not accounted for. For instance, company is considered to own one valid patent irrespective if it is validated in only one or more than one country.

depreciation is dictated by the economic nature of patents. Due to technological progress, innovations protected by patents are prone to erode with the time.

Citations to Grants, (Cg) – the measure of the stock of forward citations to granted patents. Citations are counted at the EPO for 3 years after the grant date. We use data from EPO to construct these stocks. They provide a proxy for the technological importance of the firm's inventions in the past. The stock is constructed as cumulative sum and declining balance formula is applied.

$$\mathrm{Cg}_{\mathrm{t}}^{\mathrm{stock}} = \mathrm{Cg}_{\mathrm{t}}^{\mathrm{flow}} + (1-\delta)\mathrm{Cg}_{\mathrm{t-1}}^{\mathrm{stock}} \tag{10}$$

Here $\delta = 15\%$ annual depreciation rate. In empirical model we use citations to granted patents stock scaled by the patent portfolio: (C/PT).

Citations to Applications, (C) – this is a measure of the stock of forward citations to applied patents. Citations are counted at the EPO for 3 years after the application publication date. It is also called a "broad citations" measure, while citations to granted patents represent "narrow citations" approach. We use data from EPO to construct these stocks. The stock is constructed as cumulative sum and 15% annual depreciation rate is applied. The ratio to patent application stock is used in the empirical estimation: (C/PT).

$$\mathrm{C}_{\mathrm{t}}^{\mathrm{stock}} = \mathrm{C}_{\mathrm{t}}^{\mathrm{flow}} + (1-\delta)\mathrm{C}_{\mathrm{t-1}}^{\mathrm{stock}} \tag{11}$$

Here $\delta = 15\%$ annual depreciation rate. In empirical model we use citations to applications stock scaled by the patent application stock.

Trademark stock (TM) – the size of each firm's overall trademark application portfolio. We rely on the data from EUIPO to construct this measure.

$$\mathrm{TM}_{\mathrm{t}} = \mathrm{TM}_{\mathrm{t-1}} + \mathrm{tm}_{\mathrm{t}} - \overline{\mathrm{tm}}_{\mathrm{t}} \tag{12}$$

Here TM_{t-1} is the past total stock of trademark filings $\mathrm{tm_t}$; is the inflow of new trademark filings in the current year, or trademark renewals;[18] $\overline{\mathrm{tm}}_\mathrm{t}$ is the outflow of trademarks: trademarks that were cancelled or not renewed. Due to infinite lifecycle and an economic nature of brands, depreciation rate is not applied when computing the trademark stock. Indeed, the value of the brand might even increase with the time depending on firm's investment in the product development and their marketing strategy. In the empirical model estimations we rely on the trademark stock scaled to total assets: (TM/A).

Technology area fixed effects – Firms are classified using the ICB (Industry Classification Benchmark) taxonomy. It allows us to analyze differences across different business activities. The categorization is based on ICB system of 10 industries partitioned into 19 super-sectors which are further divided into 41 sectors, which then contains 114 sub-sectors.

Time fixed effects – these are annual time dummies. Using data on the date of patent application filing at the EPO and the date of trademark application filing at the EUIPO we construct dummies to capture time fixed effects.

The above described covariates are included in the estimation models reported in the next section. We build models that rely either on the patent portfolio or the stock of applied patents in addition to the stock of R&D expenditure as a proxy for the knowledge assets. Also, we include citations to granted patents or the citations to applied patents analyzing differences between impact of "narrow" and "broad" citations to the market value. Trademark stock and operating expenditure stock are employed as additional measurement of the knowledge assets. They are included in all model specifications. The following section discusses regression results.

[18] A European Union trade mark (EUTM) is valid for 10 years. It can be renewed indefinitely, for 10 years at a time

5. EMPIRICAL RESULTS

This section outlines and discusses empirical results. Building on the EC-JRC/OECD COR&DIP data as well as on PATSTAT and EUIPO data we construct a panel dataset of the largest R&D investors worldwide. Their knowledge assets and Intellectual Property portfolios are observed. Using this data we estimate market value equations in the spirit of Hall et al. (2005). Our models include both variables capturing knowledge investments and brand investments.

The dataset employed to estimate the market value equation has the structure of an unbalanced panel. It comprises 3,235 observations on 481 companies for the years 2005 through 2012.

“Horse Race” regressions

As a first-cut estimation, a number of “horse-race” regressions were conducted. The aim of these regressions was two-fold. First, we sought to analyze stand-alone explanatory power of potential covariates to be included in the main model. Second, it allows better comparing the results of our analysis with those to previous studies.

“Horse Race” regressions are conducted as step-by-step estimations, looking into explanatory power each variable individually has on the dependent variable.

Tables 13 and 16 show the “Horse Race” regression results for the whole period, 2005-2012. Tables 14 and 17 report “Horse Race” regression results for the pre-crisis period, for the years 2005-2008 Tables 15 and 18 report “Horse Race” regression results for the post-crisis period, for the years 2009-2012.

The first set of models reported in tables 13-16 estimate individual effect of each regressor on the Tobin’s Q. The second set of models reported in tables 17-18 estimate individual effect in addition to total assets. Two types of models were considered to achieve comparability with previous studies and control the robustness of our results.

Market value is more tightly associated with the R&D stocks than with patents. R&D and patent citations emerge as the only relevant factors enhancing the market value.

When controlling for the total assets, we find that R&D fit deteriorates rather sharply in the pre-crisis period. In the post-crisis period the only two relevant factors contributing to market value are R&D stock and citations to granted patents. Trademarks and patent counts are only significant in the pre-crisis period. These outcomes are sustained by the results obtained in the full model specifications.

Estimation of main model: 2005-2012

Table 6 sets out the main estimation model results for the period 2005-2012. We investigate whether it is patent applications or patent grants that affect market value in this period. Also we address the question whether citations to patent applications or citations to granted patents are more important for investors. In addition, R&D expenditure to assets ratio is included as a proxy for the knowledge assets. Operating expenditure to assets ratio is employed as a measurement for branding activities.

The results indicate that market value is largely driven by R&D investments. This is by far the most significant and robust result across different model specifications. This result is consistent with the findings in earlier studies conducted by Hall (2000), Blundell et al. (2002), Toivanen et al. (2002), Hall and Oriani (2006), Hall et al. (2005) and Greenhalgh and Rogers (2006).

Neither patent portfolio size nor patent application counts have meaningful explanatory power in model specifications of market value equation reported in table 6.

An important issue that must be taken into consideration when interpreting these results is that we observe EPO patent applications and grants. Even though companies in the estimation sample originate mainly from the USA, and most of the companies operate in global markets. It is well worth recognizing that different results could be obtained if the equivalent USA patent measures were included in the estimations. Some previous studies reported the interdependence between EPO and US patents in market value equations. For instance, Hall et al. (2007) find that “financial markets place a positive value on EPO patented inventions owned by European firms only when patent protection is also acquired in the United States”. They report that patents taken out in only one jurisdiction have “little if any association with firm market value”, while patents taken out in both EPO and USPTO are more valuable.

Table 6: Market Value as a Function of R&D, Patents, Citations and Trade-marks, 2005-2012, OLS, dependent variable: Tobin's Q

	M1	M2	M3	M4
Variables (dependent variable: ln Tobin's Q)	**Grants/ Narrow Citations**	**Grants/ Broad Citations**	**Applications/ Narrow Citations**	**Applications/ Broad Citations**
ln R&D/Assets	1.272***	1.303***	1.274***	1.297***
	(0.307)	(0.307)	(0.308)	(0.308)
ln Patent portfolio/R&D	0.124	0.127		
	(0.123)	(0.128)		
ln Patent applications/R&D			0.153	0.186
			(0.139)	(0.144)
ln Citations/Grants	0.0660*		0.0618*	
	(0.0292)		(0.0305)	
ln Citations/Applications		0.0593		0.0523
		(0.0456)		(0.0459)
ln Opex/Assets	-2.171***	-2.226***	-2.170***	-2.225***
	(0.436)	(0.439)	(0.435)	(0.437)
ln Trademarks/Assets	0.373*	0.385*	0.370*	0.376*
	(0.159)	(0.159)	(0.160)	(0.160)
ln Assets	-0.0840***	-0.0854***	-0.0843***	-0.0867***
	(0.0129)	(0.0131)	(0.0126)	(0.0127)
Constant	3.003***	3.053***	2.991***	3.055***
	(0.505)	(0.513)	(0.500)	(0.506)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235
R2	0.386	0.382	0.386	0.382
Log-likelihood	-1144.9	-1155.7	-1144.3	-1153.8

Note Table 6: Robust standard errors in parentheses; + $p<0.10$ * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors clustered at the company level (481 clusters).

Interestingly, citations to patents granted by the EPO are perceived as a significant factor by financial markets and contribute positively to the market value of the companies. Conversely, the same does not hold when citations to patent applications are considered. They do not have explanatory power in the market value equations. Financial markets tend to recognize the quality of de-facto approved and owned patents instead of attributing enough importance to citations of only potentially economically valuable inventions.

The results reported in table 6 also indicate that both knowledge assets and trademarks are economically valued by the stock market. Both measures of investments in R&D and trademark portfolio size were positively associated with Tobin's Q when estimating period of eight years, 2005 through 2012. The contribution of trademarks to firms' market values was robust at 5% level.

Estimation of main model: Pre-crisis (2005-2008) and Post-crisis (2009-2012)

Table 7: Market Value as a Function of R&D, Patent Portfolios, Citations and Trademarks: Split samples, OLS, dependent variable: Tobin's Q

	M1 - pre	M2 - pre	M1 - post	M2 - post
Variables (dependent variable: ln Tobin's Q)	**Pre-crisis 2005-2008**		**Post-crisis 2009-2012**	
	Grants/ Narrow Citations	**Grants/ Broad Citations**	**Grants/ Narrow Citations**	**Grants/ Broad Citations**
ln R&D/Assets	0.719+	0.757*	1.873***	1.901***
	(0.368)	(0.369)	(0.339)	(0.339)
ln Patent portfolio/R&D	0.333*	0.358*	-0.114	-0.128
	(0.136)	(0.139)	(0.131)	(0.139)
ln Citations/Grants	0.0658+		0.0624*	
	(0.0370)		(0.0308)	
ln Citations/Applications		0.0382		0.0723
		(0.0490)		(0.0565)
ln Opex/Assets	-1.368**	-1.454**	-2.899***	-2.939***
	(0.509)	(0.512)	(0.451)	(0.455)
ln Trademarks/Assets	0.467*	0.486**	0.297+	0.304+
	(0.185)	(0.185)	(0.160)	(0.160)
ln Assets	-0.0854***	-0.0887***	-0.0782***	-0.0782***
	(0.0144)	(0.0146)	(0.0139)	(0.0140)
Constant	2.506***	2.618***	3.196***	3.204***
	(0.588)	(0.595)	(0.556)	(0.566)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	1463	1463	1772	1772
R2	0.395	0.392	0.409	0.405
Log-likelihood	-590.4	-594.8	-497.8	-503.9

Note Table 7: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies (pre-crisis and post-crisis), and 10 country dummies. Standard errors clustered at the company level: 445 clusters for the pre-crisis period and 477 clusters for the post-crisis period.

Table 8: Market Value as a Function of R&D, Patent Applications, Citations and Trademarks: Split samples, OLS, dependent variable: Tobin's Q

	M3 - pre	**M4 - pre**	**M3 - post**	**M4 - post**
Variables (dependent variable: ln Tobin's Q)	**Pre-crisis 2005-2008**		**Post-crisis 2009-2012**	
	Applications/ Narrow Citations	**Aplications/ Broad Citations**	**Applications/ Narrow Citations**	**Aplications/ Broad Citations**
ln R&D/Assets	0.725*	0.758*	1.863***	1.882***
	(0.369)	(0.369)	(0.342)	(0.342)
ln Patent applications/R&D	0.350*	0.392**	-0.120	-0.0887
	(0.150)	(0.151)	(0.154)	(0.165)
ln Citations/Grants	0.0596		0.0656*	
	(0.0384)		(0.0318)	
ln Citations/Applications		0.0312		0.0703
		(0.0493)		(0.0586)
ln Opex/Assets	-1.359**	-1.441**	-2.902***	-2.947***
	(0.507)	(0.508)	(0.451)	(0.455)
ln Trademarks/Assets	0.470*	0.484**	0.297+	0.298+
	(0.185)	(0.185)	(0.162)	(0.161)
ln Assets	-0.0846***	-0.0882***	-0.0789***	-0.0806***
	(0.0142)	(0.0143)	(0.0136)	(0.0137)
Constant	2.469***	2.581***	3.225***	3.264***
	(0.580)	(0.585)	(0.553)	(0.562)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	1463	1463	1772	1772
R2	0.395	0.392	0.409	0.405
Log-likelihood	-590.7	-594.3	-498.0	-504.9

Note Table 8: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies (pre-crisis and post-crisis), and 10 country dummies. Standard errors clustered at the company level: 445 clusters for the pre-crisis period and 477 clusters for the post-crisis period.

Tables 7 and 8 provide split-sample estimation results. The time period is divided into Pre-crisis years 2005-2008, and Post-crisis years 2009-2012, inclusive[19].

[19] Additionally, regression with pre- and post-crisis dummy interaction terms was done. The results are reported in Table 19 in the Appendix E. The split-sample regression results were confirmed: patent counts are only significant in the pre-crisis period; in the post-crisis period patent quality measured by citations to granted patents become relevant to the stock market valuation. Interacting covariate R&D and Total Assets ratio suggests more outspoken effect of R&D spending on the market value than the split-sample

This type of analyses is carried out in order to compare the model estimations between these two periods. Given the shock induced in financial markets by the Great Recession, it is relevant to analyze the market response to valuation of knowledge assets for each period separately. The exact timing of the crisis is rather ambiguous[20] and different time periods are considered. Since this study analyzes stock market valuation of companies, we consider the crisis duration definition that of financial markets. Financial conditions deteriorated sharply in September 2008[21]. The stress of interbank lending began to ameliorate during the fall and winter of 2008, but remained elevated until summer of 2009. Lending started rebound with a slow recovery at the end of 2009 (Chodorow-Reich, 2014). The financial crisis, considering the turmoil in interbank lending and major macroeconomic recession, is defined to last from October 2008 until June 2009[22].

Well recognizing that various repercussions of the recession have been evident for many years after 2008, we divide the estimation period into two groups: 2005-2008 and 2009-2012 as pre-crisis and post-crisis accordingly. The first period of time is considered from 2005 in order to account for more precise measures of R&D stock. R&D expenditure is by far the most truncated variable in our dataset. Broader timespan of the estimation period comes at the cost of the number of the firms to be included in the sample. Therefore, 2005 as the starting year of the analysis was chosen as an optimal solution. The final year in the estimation period is 2012 due to IP data availability. Reliable measures of patent and trademark statistics are collected until this year. Even though trademark and patent application counts might have been available

regression. Nevertheless, both estimations suggest that R&D gains more importance and has stronger positive effect on companies' market value in the post-crisis period of 2009-2012, than in the pre-crisis period of 2005-2008.

[20] The first signs of the possibility of problems at major financial institutions came in June 2007, with the rescue by the investment bank Bear Stearns of a subsidiary hedge fund (Chodorow-Reich, 2014). Financial conditions deteriorated sharply in September

[21] On September 15 Lehman Brothers filed for bankruptcy.

[22] The choice of June 2009 as terminal month reflects both the timing of the US recession, which ended that month, and the timing of the return to normalcy in the interbank lending market.

until 2014, patent grant statistics are truncated due to long patent application examination periods at the EPO.

Market value is estimated based on equation 5 reported in the section 3.1. Patent portfolio is used in Table 7, while patent application stocks are used in Table 8.

The result that emerges as robust and holds in all model specifications is that R&D stock to Assets ratio and Operating expenses to Assets ratios have much larger coefficients in the years after the financial crisis than in the years before. More work will be required to analyze this result, but it may point to a premium for efforts to escape the drag of the crisis by investing in new opportunities.

Throughout all model specifications reported in Tables 7 and 8, we observe that in the pre-crisis period R&D stock coefficient is around 0.7. In the post-crisis period however, R&D stock effect increased substantially, reaching 1.8, and is highly robust at 0.1% level.

The opposite is observed when estimating patent portfolio to R&D ratio or patent application stock to R&D ratio. In the pre-crisis period patent productivity shows rather large effect on firm's market value with coefficient of 0.3. In the post-crisis period however this effect is no longer significant.

In general, patents vary enormously in terms of underlying value. Patent counts alone might not be sufficient indicator to be regarded by the stock markets. The purpose of including the patent counts weighted by citations in the empirical analysis was to obtain the indicator of the value of innovations patented by firms. Many of the previous econometric studies, e.g. by Bloom and van Reenen (2002), Hall et al. (2005), Thoma (2015), found that patent stock enhances Tobin's Q. Nevertheless, several recent studies, e.g. Sandner and Block (2011) found that patent stock was not contributing significantly to the market value and rather patent quality measures or trademark stocks emerged as robust market value enhancers. As indicated by Trajtenberg (1990), "the use of patents in economic research has been seriously hindered by the fact that patents vary enormously in their importance or value, and hence, simple patent counts cannot be informative about innovative output." In his article Trajtenberg (1990) shows that particular innovation (Computed Tomography scanners) is closely associated with citation-based patent indices and independent measures of the social value of innovations in that field. Thoma (2015) provides evidence that when index of patent family value distribution is taken into account, the return of the value of weighted patents are of comparable scale to that of R&D investment, confirming the view that financial markets are capable to discriminate the value heterogeneity of firm's patent assets (Hall et al., 2005; Lanjouw and Schankerman, 2004; Thoma, 2015).

We consider patent citations measure to account for the quality of patents. Results suggest that citations to granted patents obtain more significance in the post-crisis years, as significance level increases from marginal 10% level up to 5% level. Citations to applied patents were not observed as a relevant element neither in pre-crisis nor in post-crisis period however.

Trademarks arise in the estimation equation as a separate variable. Trademark stock is a positive and significant factor in the pre-crisis period of 2005-2008 throughout all model specifications. However, we find that in the post-crisis period, the effect of trademark stock on the value of companies erodes. The coefficient is still positive, but reduces nearly by half. The effect of trademarks also loses its significance in the post-crisis period as compared to pre-crisis period. These results must be taken with a pinch of salt. Similarly as patents, we only observe European trademarks in this study. Measures of US or other trademarks in case they were additionally included in the analysis might provide different results. However, we believe that the European trademark portfolios serve as a good proxy for companies overall trademarking activity. The pattern that emerges comparing pre-crisis and post-crisis periods holds for both patents and trademarks. It suggests that the mere counts of these IP rights are no longer a sufficient factor to enhance the firm's value.

The main shortcomings of the estimation stem from unobserved heterogeneity and sample selection bias. Our company sample represents large and mostly multinational enterprises that are among the top 2000 R&D investors in the world. Average market value of these companies is 13 billion euros and average annual R&D budget is around 357 million euros. Nevertheless, it is worth mentioning that this type of empirical analysis is possible only for publicly listed companies for which the market capitalization and market value data is accessible.

Also, one may worry that findings are affected to some extent by unobserved heterogeneity. Variables such as R&D expenditure, patent and trademark portfolios might be correlated with unobserved company characteristics. Among those, managerial quality and firm strategy toward Intellectual Property must be named as important yet unobserved company features. Companies behave differently and react in different manner in the time of crisis. In this paper we seek to explore whether economic recession has caused markets to value the investments in knowledge capital more or less comparing two periods, pre-crisis and post-crisis. When faced with sudden and severe financing restrictions companies have made decisions based on their internal policies. The element of turmoil together with the time shortage has caused the lack of coordination between the rivals. Based on this assumption we believe that the company behavior during the financial crisis was impacted largely by the management quality and only subsequently by the actions of their rivals.

The next section summarizes findings of this study and provides concluding remarks.

6. CONCLUSIONS

Innovation and productivity are the topics that fascinate economists since the very beginning of the study of economics. Nearly half a century ago the insight was made that economic growth could not be explained on the basis of the traditional factors of production of land, labor and capital alone. Rather a large residual factor in growth was attributed to improvements in productivity consequent on technological progress or innovation (Solow, 1957). During the 1980s and 1990s economists' interest in the possible role of knowledge (technology) for growth and development increased. On the theoretical front an important development was the emergence of new growth theory (e.g. Romer, 1990) according to which endogenous knowledge accumulation accounts for differences in economic development across the countries.

The macroeconomic rationale is well applied in microeconomic setting when analyzing company level market value premium. Intangible assets such as knowledge stock and intellectual property are recognized as significant factors that enhance the value of the companies.

Most of the prior literature considered R&D expenditure and patents as factors in the market value equation. Patent citations as a measure for the patent quality were studied by Hall et al. (2005), who were among the first researchers to incorporate citations in Tobin’s Q model and to our knowledge have conducted the largest-scale study. With the exception of the studies by Greenhalgh and Rogers (2006), Sandner and Block (2011), Block et al. (2014) and Thoma (2015), previous studies rarely consider marketing activities and brands in the market value equations alongside with R&D and patents. There is a lack in debate and empirical evidence regarding the value that trademarks or branding expenditure generates for the companies, and the way it is perceived by financial markets.

This main novel contribution of this study is empirical analysis of the market value equation in the context of recent Great Recession. The rich and novel dataset that we built for this analysis collects information on both patent and trademark stocks, alongside with patent citations. R&D and operating expenditure accounts for the knowledge assets and branding expenditure. This study is also among the few studies which incorporate patent citations in the model estimation and attempts to analyze how trademark portfolios affect the Tobin’s Q.

Our findings are in line with those of the previous studies suggesting that market value is largely driven by R&D investments. This result is the most robust one across different model specifications through periods 2005-2012, 2005-2008 and 2009-2012.

An interesting pattern was discovered when analyzing patent counts and patent citations’ impact on the market value of the companies during pre-crisis and post-crisis periods. It becomes apparent that in the pre-crisis period patent portfolio size as well as patent application stock were perceived as significant factors by financial markets. They contributed to the enhancement of the market value premium of the companies. Citations to patents was not relevant factor in the pre-crisis period.

Conversely, in the post-crisis period an opposite holds. We observe the deteriorated significance in patent counts and emerged significance of the citations to granted patents. These results indicate that financial markets value the quality of innovation rather than mere patent counts in the post-crisis period.

A similar pattern is found when comparing the effect of trademark stock. In the pre-crisis period companies owning more European trademarks are valued above their reported assets and generate premium to the firm's price in financial markets. No significance is attributed to the trademark stock when estimating market value equations for the post-crisis period during 2009-2012. It allows us to speculate on the possibility that a trademark quality measure might be regarded as an important factor and reflect positive influence toward market value

Overall, the main findings points to conclusion that in the post-crisis period two factors emerges as significant market value enhancers. The first is the knowledge stock approximated by R&D expenditure stock. The second is the quality of innovation generated by R&D, approximated by the patent citations.

More work will be required to analyze this result, but it may suggest the efforts to escape the drag of the crisis by investing in new opportunities. On the other hand, financial markets may have shifted their attention to the innovation behind the legal IP rights. Patent counts that serve as strategic instruments and comprise patent thickets might not be deemed as relevant for the firm's value premium but rather the cutting-edge technology that has a true potential in generating demand for companies products. By the same logic, the value of the brand might become the factor discriminated by the financial markets.

These findings shed the light on change in perception of the stock markets toward innovation in the context of the Great Recession. They also suggest that the companies' willingness to invest in scientific capabilities might have been increased in the aftermath of the economic crisis.

Our empirical analysis complements previous studies which analyze the trends of corporate research. For instance, Arora et al. (2015) provide evidence that over the long run of 1980-2007 publicly traded American companies diminished their investment in research significantly. At the same time, patenting activity by firms has increased. This shows that the pattern of corporate innovation strategy was sustained over the long period of time before the economic crisis of 2008.

The significant boost in market value premium generated by firms' investment in science, points to the possible shift in corporate research strategies. The results of our analysis clearly indicate both the importance placed to R&D investments by both stock markets and companies. In the post-crisis period the importance of patent stocks is diminished however. Hence we may observe the development of the novel trend of higher valuation of the firm's scientific capabilities rather than patents themselves. One caveat of our analysis is the brevity of the time period observed. It is also possible that an increase in R&D will result in larger patent portfolios generated over longer period of time. The change in market valuation of the knowledge assets might prove to be either the new long-term pattern, or the short-term turmoil caused by the crisis. These questions provide the base for future research possibilities.

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LIST OF ABBREVIATIONS

EC-JRC – European Commission Joint Research Centre

EU – European Union

EPO – European Patent Office

EUIPO – European Intellectual Property Office

ICB – Industry Classification Benchmark

IP – Intellectual Property

IPR – Intellectual Property Right(s)

IPTS – Institute for Prospective Technological Studies

NICE – Nice Agreement Concerning the International Classification of Goods and Services for the Purposes of the Registration of Marks

OECD – Organization for Economic Co-operation and Development

OPEX – Operational Expenditure

PATSTAT – EPO Worldwide Patent Statistical Database

R&D – Research and Development

TQ – Tobin's Q

APPENDIX

APPENDIX A. BUILDING PROCESS OF THE ESTIMATION SAMPLE DATASET

The matching of EC-JRC/OECD COR&DIP data as well as of PATSTAT and EUIPO datasets could be broadly divided into several steps:

a. COR&DIP Matching with PATSTAT

The aim of this exercise was to find all the patents that were filed at the EPO at any time during 1978-2015 and belonged to the top 2000 global R&D investing firms as identified by COR&DIP.
The matching was carried out as following algorithm:

i. Link COR&DIP and PATSTAT based on the unique EPO patent application identifier.
ii. Identify the same group of companies, and assign these companies with patent applications filed during 1978-2015.

b. COR&DIP matching with EUIPO

The aim of this exercise was to find all the trademark applications that were filed at the EUIPO at any time during 1996-2014 and belonged to the top 2000 global R&D investing firms as identified by COR&DIP. The matching was carried out as following algorithm:

i. Link COR&DIP and EUIPO based on unique trademark number common for both databases.

ii. Identify the same group of companies and assign patent applications filed during 1996-2014.

c. **Link PATSTAT and EUIPO data for top 2000 R&D investing companies together based on unique company identifier provided by COR&DIP.**

d. **Link joint patent and trademark dataset with Bureau van Dijk Amadeus dataset.**

The aim of this exercise was to retrieve financial data for the European companies. The link was carried out on the basis on firm name. In this case we could not rely on a unique numerical identifier as in case of matching with PATSTAT and EUIPO. The matching was carried out as following algorithm:

i. In order to simplify the task of manual matching of firm names, we identified the first word in the name of each company.
ii. The matching was performed on the basis of the first word in each firm's name and its geographical location – country code.
iii. We carried out manual control of each match and identified true and false matches.
iv. In case of multiple matches we identified the correct link.
v. In case of false positive or false negative matches, additional name search was carried out in the database of Amadeus.

e. **Link joint patent and trademark dataset with COMPUSTAT dataset.**

The aim of this exercise was to retrieve financial data for the non-European companies. In the same manner as in matching with Amadeus data, the link was carried out on the basis on firm name and following the same algorithm as indicated in above section d.

APPENDIX B. SUMMARY OF PRIOR ART

Table 9: Empirical studies of the market value and innovation

Paper	R&D	Patents	Citations	TM	Sample	Geographical coverage	Time period
Griliches (1984)	YES	YES	NO	NO	1.091	USA	1968-1974
Megna and Klock (1993)	YES	USPTO	NO	NO	11	USA	1977-1990
Hall (1998)	YES	YES	NO	NO	5.000	USA	1976-1995
Blundell et al. (1999)	NO	USPTO	NO	NO	340	UK	1972-1982
Bloom and Van Reenen (2002)	NO	USPTO	YES	NO	404	UK	1968-1996
Toivanen et al. (2002)	YES	NO	NO	NO	1.519	UK	1988-1995
Hall, Jaffee and Trajtenberg (2005)	YES	USPTO	YES	NO	1.982	USA	1979-1988
Greenhalgh and Rogers (2006)	YES	UK, EPO	NO	EUIPO	3.227	UK	1989-2002
Hall and Oriani (2006)	YES	NO	NO	NO	2.156	US, UK, FR, IT, DE	1989-1998
Hall, Thoma and Torrisi (2007)	YES	USPTO, EPO	YES	NO	7.168	Europe (21)	1991-2002
Sandner and Block (2011)	YES	EPO	YES	EUIPO	1.216	EU	1996-2002
Thoma (2015)	YES	USPTO, EPO	NO	USPTO	4.780	USA, Europe	1991-2005
Our study	YES	EPO	YES	EUIPO	481	BE, CA, CH, CW, DE, FR, IL, NL, SG, US	2005-2012

APPENDIX C. ESTIMATION SAMPLE CHARACTERISTICS

Table 10: Estimation Sample Characteristics: Correlation of Variables, 2005-2012

	ln Tobin's Q	ln Assets	ln R&D/Assets	ln Patent portfolio/ R&D	ln Patent applications/ R&D	ln Citations/ Grants	ln Citations/ Applications	ln Opex/ Assets	ln Trademarks/ Assets
ln Tobin's Q	1								
ln Assets	-0.3105* 0.0000	1							
ln R&D/Assets	0.1981* 0.0000	-0.2992* 0.0000	1						
ln Patent portfolio/R&D	-0.1431* 0.0000	0.5367* 0.0000	-0.1204* 0.0000	1					
ln Patent applications/R&D	-0.1057* 0.0000	0.5228* 0.0000	-0.0755* 0.0000	0.9496* 0.0000	1				
ln Citations/Grants	0.2005* 0.0000	-0.0578* 0.0010	0.1153* 0.0000	0.0905* 0.0000	0.1892* 0.0000	1			
ln Citations/Applications	0.2002* 0.0000	-0.0286 0.1034	0.0928* 0.0000	0.1668* 0.0000	0.2241* 0.0000	0.6117* 0.0000	1		
ln Opex/Assets	-0.0212 0.2282	-0.3474* 0.0000	0.2524* 0.0000	-0.2314* 0.0000	-0.2222* 0.0000	-0.0811* 0.0000	-0.1209* 0.0000	1	
ln Trademarks/Assets	-0.0711* 0.0001	0.5925* 0.0000	-0.1052* 0.0000	0.4600* 0.0000	0.4635* 0.0000	0.0481* 0.0062	0.0836* 0.0000	-0.1390* 0.0000	1

Note Table 10: Significance level of each correlation coefficient in parentheses; * p<0.05; correlation of variables in the estimation sample which contains 3,235 observations and 481 companies. Observation period: 2005-2012.

Table 11: Estimation Sample Characteristics: Correlation of Variables, 2005-2008

	ln Tobin's Q	ln Assets	ln R&D/Assets	ln Patent portfolio/ R&D	ln Patent applications/ R&D	ln Citations/ Grants	ln Citations/ Application s	ln Opex/ Assets	ln Trademarks/ Assets
ln Tobin's Q	1								
ln Assets	-0.2730* 0.0000	1							
ln R&D/Assets	0.1294* 0.0000	-0.1993* 0.0000	1						
ln Patent portfolio/R&D	-0.0651* 0.0127	0.5382* 0.0000	-0.0005 0.9849	1					
ln Patent applications/R&D	-0.0312 0.2332	0.5110* 0.0000	0.0200 0.4455	0.9633* 0.0000	1				
ln Citations/Grants	0.2037* 0.0000	-0.0806* 0.0020	0.1208* 0.0000	0.1311* 0.0000	0.2028* 0.0000	1			
ln Citations/Applications	0.2009* 0.0000	-0.0404 0.1220	0.0975* 0.0002	0.1788* 0.0000	0.2351* 0.0000	0.7241* 0.0000	1		
ln Opex/Assets	-0.0189 0.4691	-0.3005* 0.0000	0.1864* 0.0000	-0.1949* 0.0000	-0.1811* 0.0000	-0.0705* 0.0070	-0.1133* 0.0000	1	
ln Trademarks/Assets	-0.0247 0.3450	0.5943* 0.0000	-0.0439 0.0933	0.4705* 0.0000	0.4648* 0.0000	0.0623* 0.0172	0.0858* 0.0010	-0.1101* 0.0000	1

Note Table 11: Significance level of each correlation coefficient in parentheses; * p<0.05; correlation of variables in the estimation sample which contains 1,463 observations and 445 companies. Observation period: 2005-2008.

Table 12: Estimation Sample Characteristics: Correlation of Variables, 2009-2012

	ln Tobin's Q	ln Assets	ln R&D/Assets	ln Patent portfolio/ R&D	ln Patent applications/ R&D	ln Citations/ Grants	ln Citations/ Application s	ln Opex/ Assets	ln Trademarks/ Assets
ln Tobin's Q	1								
ln Assets	-0.3449* 0.0000	1							
ln R&D/Assets	0.2977* 0.0000	-0.4364* 0.0000	1						
ln Patent portfolio/R&D	-0.2248* 0.0000	0.5480* 0.0000	-0.1761* 0.0000	1					
ln Patent applications/R&D	-0.1854* 0.0000	0.5389* 0.0000	-0.1597* 0.0000	0.9425* 0.0000	1				
ln Citations/Grants	0.2006* 0.0000	-0.0424 0.0745	0.1083* 0.0000	0.0629* 0.0081	0.1803* 0.0000	1			
ln Citations/Applications	0.2002* 0.0000	-0.0177 0.4576	0.0957* 0.0001	0.1578* 0.0000	0.2120* 0.0000	0.5179* 0.0000	1		
ln Opex/Assets	-0.0193 0.4158	-0.3984* 0.0000	0.2736* 0.0000	-0.2508* 0.0000	-0.2615* 0.0000	-0.0949* 0.0001	-0.1325 0.0000	1	
ln Trademarks/Assets	-0.1112* 0.0000	0.5894* 0.0000	-0.2063* 0.0000	0.4687* 0.0000	0.4693* 0.0000	0.0349 0.1423	0.0818* 0.0006	-0.1773* 0.0000	1

Note Table 12: Significance level of each correlation coefficient in parentheses; * p<0.05; correlation of variables in the estimation sample which contains 1,772 observations and 477 companies. Observation period: 2009-2012.

APPENDIX D. “HORSE RACE” REGRESSIONS

Table 13: “Horse Race” Regressions of R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2012: OLS Model with Dependent Variable: log Tobin’s Q

Variables (dependent variable: ln Tobin's Q)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
ln Assets	-0.0475***									
	(0.00937)									
ln R&D/Assets		0.963**								
		(0.292)								
ln Patent portfolio/R&D			-0.139							
			(0.113)							
ln Patent portfolio/Assets				-0.125						
				(0.132)						
ln Patent applications/R&D					-0.0982					
					(0.125)					
ln Patent applications/Assets						-0.0537				
						(0.145)				
ln Citations/Grants							0.0883**			
							(0.0322)			
ln Citations/Applications								0.0880+		
								(0.0478)		
ln Opex/Assets									-0.386	
									(0.399)	
ln Trademarks/Assets										-0.170
										(0.132)
Constant	1.481***	-0.100	0.822***	0.816***	0.819***	0.804***	0.720***	0.714***	1.197**	0.811***
	(0.140)	(0.271)	(0.0417)	(0.0428)	(0.0501)	(0.0519)	(0.0406)	(0.0505)	(0.424)	(0.0358)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235	3235	3235	3235	3235	3235	3235
R2	0.339	0.322	0.312	0.311	0.311	0.310	0.320	0.313	0.311	0.312
Log-likelihood	-1263.7	-1305.7	-1329.1	-1330.9	-1331.7	-1333.1	-1308.7	-1324.9	-1330.7	-1329.0

Note Table 13: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin’s Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors are clustered at the company level (481 clusters).

Table 14: "Horse Race" Regressions of R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2008: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
ln Assets	-0.0379***									
	(0.0106)									
ln R&D/Assets		0.559+								
		(0.339)								
ln Patent portfolio/R&D			0.0950							
			(0.127)							
ln Patent portfolio/Assets				0.136						
				(0.150)						
ln Patent applications/R&D					0.128					
					(0.136)					
ln Patent applications/Assets						0.188				
						(0.160)				
ln Citations/Grants							0.103**			
							(0.0392)			
ln Citations/Applications								0.0830		
								(0.0551)		
ln Opex/Assets									-0.184	
									(0.462)	
ln Trademarks/Assets										0.0172
										(0.150)
Constant	1.201***	0.173	0.634***	0.628***	0.621***	0.610***	0.583***	0.588***	0.855+	0.658***
	(0.153)	(0.295)	(0.0478)	(0.0482)	(0.0530)	(0.0535)	(0.0475)	(0.0599)	(0.493)	(0.0399)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1463	1463	1463	1463	1463	1463	1463	1463	1463	1463
R2	0.358	0.345	0.342	0.343	0.343	0.344	0.353	0.345	0.342	0.342
Log-likelihood	-634.4	-648.5	-651.6	-651.1	-651.0	-650.2	-639.5	-648.5	-652.3	-652.5

Note Table 14: Robust standard errors in parentheses; + $p<0.10$ * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (445 clusters).

Table 15: "Horse Race" Regressions of R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2009-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**
ln Assets	-0.0548***									
	(0.00995)									
ln R&D/Assets		1.400***								
		(0.355)								
ln Patent portfolio/R&D			-0.370**							
			(0.118)							
ln Patent portfolio/Assets				-0.360**						
				(0.135)						
ln Patent applications/R&D					-0.358**					
					(0.136)					
ln Patent applications/Assets						-0.309*				
						(0.155)				
ln Citations/Grants							0.0785*			
							(0.0363)			
ln Citations/Applications								0.0894+		
								(0.0538)		
ln Opex/Assets									-0.537	
									(0.432)	
ln Trademarks/Assets										-0.324*
										(0.138)
Constant	1.575***	-0.519	0.866***	0.858***	0.889***	0.867***	0.719***	0.706***	1.352**	0.822***
	(0.148)	(0.333)	(0.0431)	(0.0442)	(0.0536)	(0.0554)	(0.0423)	(0.0534)	(0.462)	(0.0359)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1772	1772	1772	1772	1772	1772	1772	1772	1772	1772
R2	0.337	0.319	0.307	0.304	0.303	0.299	0.303	0.297	0.296	0.301
Log-likelihood	-599.9	-624.0	-639.2	-643.8	-644.3	-649.4	-644.0	-652.4	-653.1	-646.7

Note Table 15: Robust standard errors in parentheses; + $p<0.10$ * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (477 clusters).

Table 16: "Horse Race" Regressions of Total Assets, R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
ln Assets	-0.0475***	-0.0432***	-0.0583***	-0.0602***	-0.0479***	-0.0488***	-0.0610***	-0.0642***
	(0.00937)	(0.00928)	(0.0114)	(0.0110)	(0.00902)	(0.00923)	(0.00975)	(0.0117)
ln R&D/Assets		0.687*						
		(0.282)						
ln Patent portfolio/R&D			0.226+					
			(0.132)					
ln Patent applications/R&D				0.306*				
				(0.142)				
ln Citations/Grants					0.0903**			
					(0.0283)			
ln Citations/Applications						0.104*		
						(0.0461)		
ln Opex/Assets							-1.341***	
							(0.404)	
ln Trademarks/Assets								0.378*
								(0.161)
Constant	1.481***	0.784**	1.585***	1.574***	1.417***	1.412***	3.094***	1.676***
	(0.140)	(0.301)	(0.154)	(0.145)	(0.136)	(0.139)	(0.493)	(0.165)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235	3235	3235	3235	3235
R2	0.339	0.345	0.342	0.344	0.350	0.344	0.351	0.345
Log-likelihood	-1263.7	-1249.6	-1255.1	-1250.5	-1236.5	-1251.2	-1232.7	-1249.1

Note Table 16: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors are clustered at the company level (481 clusters).

Table 17: “Horse Race” Regressions of Total Assets, R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2005-2008: OLS Model with Dependent Variable: log Tobin’s Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
ln Assets	-0.0379***	-0.0368***	-0.0601***	-0.0599***	-0.0379***	-0.0395***	-0.0444***	-0.0631***
	(0.0106)	(0.0106)	(0.0118)	(0.0114)	(0.0102)	(0.0105)	(0.0110)	(0.0129)
ln R&D/Assets		0.476						
		(0.330)						
ln Patent portfolio/R&D			0.446**					
			(0.138)					
ln Patent applications/R&D				0.489***				
				(0.147)				
ln Citations/Grants					0.103**			
					(0.0369)			
ln Citations/Applications						0.0964+		
						(0.0523)		
ln Opex/Assets							-0.775+	
							(0.466)	
ln Trademarks/Assets								0.556**
								(0.182)
Constant	1.201***	0.770*	1.393***	1.363***	1.123***	1.139***	2.114***	1.498***
	(0.153)	(0.332)	(0.157)	(0.152)	(0.150)	(0.154)	(0.559)	(0.178)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1463	1463	1463	1463	1463	1463	1463	1463
R2	0.358	0.360	0.371	0.372	0.369	0.363	0.362	0.369
Log-likelihood	-634.4	-631.4	-618.9	-617.6	-621.1	-628.9	-630.1	-621.5

Note Table 17: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin’s Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (445 clusters).

Table 18: "Horse Race" Regressions of Total Assets, R&D, Patents, Patent Citations, Trademarks and Operating expenditure, 2009-2012: OLS Model with Dependent Variable: log Tobin's Q

Variables (dependent variable: ln Tobin's Q)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
ln Assets	-0.0548***	-0.0463***	-0.0546***	-0.0577***	-0.0554***	-0.0557***	-0.0758***	-0.0646***
	(0.00995)	(0.00954)	(0.0129)	(0.0125)	(0.00966)	(0.00991)	(0.0104)	(0.0126)
ln R&D/Assets		0.918**						
		(0.339)						
ln Patent portfolio/R&D			-0.00555					
			(0.148)					
ln Patent applications/R&D				0.0740				
				(0.165)				
ln Citations/Grants					0.0820**			
					(0.0314)			
ln Citations/Applications						0.106+		
						(0.0555)		
ln Opex/Assets							-1.864***	
							(0.433)	
ln Trademarks/Assets								0.225
								(0.166)
Constant	1.575***	0.599+	1.573***	1.595***	1.518***	1.499***	3.860***	1.688***
	(0.148)	(0.352)	(0.170)	(0.159)	(0.143)	(0.146)	(0.533)	(0.176)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1772	1772	1772	1772	1772	1772	1772	1772
R2	0.337	0.347	0.337	0.337	0.348	0.342	0.363	0.340
Log-likelihood	-599.9	-586.6	-599.9	-599.5	-585.3	-593.7	-564.3	-596.7

Note Table 18: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 3 year dummies and 10 country dummies. Standard errors are clustered at the company level (477 clusters).

APPENDIX E. ADDITIONAL EMPIRICAL ANALYSIS

Table 19: Market Value as a Function of R&D, Patents, Citations and Trade-marks, OLS, dependent variable: Tobin's Q

Variables (dependent variable: ln Tobin's Q)	M1	M2	M3	M4
	Grants/ Narrow citations	Grants/ Broad citations	Applications/ Narrow citations	Applications/ Broad citations
ln Assets - pre	-0.0918***	-0.0944***	-0.0915***	-0.0945***
	(0.0137)	(0.0139)	(0.0135)	(0.0135)
ln Assets - post	-0.0773***	-0.0775***	-0.0773***	-0.0790***
	(0.0138)	(0.0139)	(0.0135)	(0.0136)
ln R&D/Assets - pre	1.111**	1.139***	1.113**	1.136***
	(0.342)	(0.342)	(0.342)	(0.342)
ln R&D/Assets - post	1.379***	1.410***	1.387***	1.409***
	(0.313)	(0.313)	(0.316)	(0.315)
ln Patent portfolio/R&D - pre	0.315*	0.330*		
	(0.132)	(0.135)		
ln Patent portfolio/R&D - post	-0.0671	-0.0784		
	(0.133)	(0.140)		
ln Patent applications/R&D - pre			0.348*	0.381**
			(0.145)	(0.147)
ln Patent applications/R&D - post			-0.0844	-0.0517
			(0.155)	(0.165)
ln Citations/Grants - pre	0.0596+		0.0529	
	(0.0357)		(0.0372)	
ln Citations/Grants - post	0.0666*		0.0690*	
	(0.0304)		(0.0313)	
ln Citations/Applications - pre		0.0418		0.0326
		(0.0463)		(0.0466)
ln Citations/Applications - post		0.0779		0.0770
		(0.0560)		(0.0577)

ln Opex/Assets - pre	-1.991***	-2.045***	-1.994***	-2.051***
	(0.454)	(0.456)	(0.453)	(0.454)
ln Opex/Assets - post	-2.343***	-2.390***	-2.344***	-2.390***
	(0.453)	(0.456)	(0.453)	(0.455)
ln Trademarks/Assets - pre	0.466*	0.486**	0.466*	0.481**
	(0.181)	(0.181)	(0.181)	(0.181)
ln Trademarks/Assets - post	0.313+	0.319*	0.314+	0.312+
	(0.161)	(0.160)	(0.162)	(0.162)
Constant	3.049***	3.061***	3.049***	3.082***
	(0.537)	(0.546)	(0.533)	(0.541)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235
R2	0.390	0.386	0.390	0.387
Log-likelihood	-1133.1	-1142.9	-1132.9	-1142.3

Note Table 19: Robust standard errors in parentheses; + p<0.10 * p<0.05, ** p<0.01, *** p<0.001. The dependent variable is a natural logarithm of Tobin's Q. Estimator is ordinary least squares (OLS). All regressions include 25 industry dummies, 7 year dummies and 10 country dummies. Standard errors clustered at the company level (481 clusters). Covariate names with "-pre" specification indicates the interaction with pre-crisis dummy: the period 2005-2008. Covariate names with "-post" specification indicates the interaction with post-crisis dummy: the period 2009-2012.

Table 20: Descriptive Statistics, Pre-crisis and Post-crisis periods, t-test statistics

Variables	Pre-Crisis 2005-2008 Mean	Post-Crisis 2009-2012 Mean	Diff. in means	t-test	Ha: diff < 0 Pr(T < t)	Ha: diff != 0 Pr(|T| > |t|)	Ha: diff > 0 Pr(T > t)
Market value, mln EUR	12.754	13.203	448	0,4006	0,6556	0,6887	0,3444
Total Assets, mln EUR	10.977	13.074	2.097	1,6824	0,9537	0,0926	0,0463
R&D, mln EUR	229	462	232	7,2999	1,0000	0,0000	0,0000
R&D stock, mln EUR	887	1.585	698	6,0035	1,0000	0,0000	0,0000
Operating expenditure, mln EUR	5.003	5.552	550	0,9647	0,8326	0,3348	0,1674
Operating expenditure stock, mln EUR	22.577	28.559	5.982	2,1277	0,9833	0,0334	0,0167
Patent applications	102	83	-19	-1,9994	0,0228	0,0456	0,9772
Patent applications stock	506	484	-22	-0,4403	0,3299	0,6597	0,6701
Patent portfolio	439	353	-86	-2,3925	0,0084	0,0168	0,9916
Citations to applications	119	105	-14	-1,0189	0,1542	0,3083	0,8458
Citations to applications stock	593	597	4	0,0719	0,5287	0,9427	0,4713
Citations to grants	47	30	-17	-4,3633	0,0000	0,0000	1,0000
Citations to grants stock	280	242	-38	-1,5865	0,0564	0,1127	0,9436
Trademark applications	6	7	1	1,5623	0,9408	0,1183	0,0592
Trademark portfolio	59	79	20	3,7045	0,9999	0,0002	0,0001
Regression Variables	**Mean**	**Mean**					
TQ	1,703	1,575	-0,128	-2,1915	0,0142	0,0285	0,9858
R&D/Assets	0,144	0,276	0,132	13,3207	1,0000	0,0000	0,0000
Patent portfolio/R&D*1000	0,762	0,300	-0,462	-10,6156	0,0000	0,0000	1,0000
Patent applications/R&D*1000	0,865	0,408	-0,458	-10,4151	0,0000	0,0000	1,0000
Citations/Grants	1,252	1,349	0,098	0,8682	0,8073	0,3853	0,1927
Citations/Applications	1,404	1,313	-0,092	-1,7831	0,0373	0,0747	0,9627
Opex/Assets	2,570	2,945	0,374	5,1566	1,0000	0,0000	0,0000
Trademarks/Assets*1000	0,013	0,015	0,002	2,3630	0,9909	0,0182	0,0091
Observations	1.463	1.772					
Firms	445	477					

Note Table 20: t-test statistics of the variables reported in Table 2. Two-sample t test with equal variances; diff = mean(postcrisis) - mean(precrisis); Ho: diff = 0; degrees of freedom = 3233.