SELINUS UNIVERSITY
OF SCIENCES AND LITERATURE

Empirical Model for Automatic Patent Evaluation Based on Bibliometric Data

By Andreas Zagos

A DISSERTATION

Presented to the Department of
Financial Management
program at Selinus University

Faculty of Business & Media
in fulfillment of the requirements
for the degree of Doctor of Philosophy
in Financial Management

2025

Abstract

The measurement of patent quality is crucial in understanding innovation's role in predicting future technological and economic trends. This work proposes a novel model utilizing three bibliometric indicators to assess patent quality: Market Impact (Mi), Technology Impact (Ti), and Assignee Impact (Ai).

Market Impact (Mi) is determined by the size of the patent family, reflecting the market reach and commercial potential of the patent. Technology Impact (Ti) is measured through the number of citations a patent receives, indicating its influence and significance within the technological domain. Assignee Impact (Ai) is derived from a combination of factors including the number of alive patent families, the number of employees, and the total assets of the assignee, providing a comprehensive view of the patent holder's innovation capacity and stability.

To validate this model, a proof of concept was conducted by analyzing stock exchange indexes. The results demonstrate that equities associated with high-value patent portfolios significantly outperform their peers, underscoring the predictive power of these improved bibliometric indicators in assessing patent quality.

This work offers a robust framework for policymakers, investors, and researchers to gauge the potential future impact of innovations through a refined understanding of patent quality.

Acknowledgements

I would like to express my deepest gratitude to my colleagues and peers, especially my brother, Dr. Joannis Zagos, Dr. Dierk-Oliver Kiehne and Dr. Markus Dollmann, who assisted me with various aspects of my research and provided me with all the necessary data I needed, especially for the backtests.

I am forever indebted to my parents, who unfortunately passed away and will not be able to come to my dissertation party.

To my wife, Dr. Ioanna Maria Karagouni and my children, Andronikos and Artemis thank you for your unwavering support and encouragement during this challenging time.

This dissertation is dedicated to all of you.

Thank you.

Table of Contents

List of Tables

List of Figures

Chapter 01: Introduction and aim of the study

1.1 Backround of the study

Mathematical model to improve indicators for measurement of a patent quality. The mathematical model is proved for different use cases, especially their use as fundamental indicator for rating companies for asset management purposes.

1.2 Statement of the problem

In scientific literature up to 20 different indicators build from bibliometric data for measurement of patent quality are known. But the power of expression of those indicators are different and in the world of patent experts not undisputed. Therefore, a proof of concept should be undertaken to determine a simple indicator model with highest interpretation force. The use cases for measurement of patent quality are:

1.2.1. Portfolio Management & Monetization

- Patent sales/purchases
- Licensing/cross-licensing agreements
- IP valuation for funding
- IP valuation for court proceedings
- In-kind contributions to joint ventures
- Technology benchmarks
- Market assessments

1.2.2. Financials

- M&A purchase price allocation
- Base Erosion and Profit Shifting (BEPS) of OECD, Chapter 8: “Hard-To-Value Intangibles“.
- Portfolio valuations for transfer pricing and due diligence
- Balancing of intangible assets (IFRS) for reducing interest rate
- Shareholder interests, stock value
- Contributions of the research theme to knowledge development

- Structure of the research report

1.3 Research projects and publications in the research context

The following research projects have been done in the past where the author participated:

- IP4SME: Toolbox for monetizing Intellectual Property Rights, notable patents, especially designed for SMEs, funded under Eurostars, Reference Number: 9195, years 2015-2017
- CoraPatents: Fundamental Company Rating for SMEs based on Patents, funded under Eurostars, Number: 9195, years 2017-2019 with Reference Number: 11618

1.4 Publications

- Ichiro Nakatomi, Andreas Zagos, Dana Colarulli, LESI’s SDG-IP Index: Using Quality Of Life Aspects–And Intellectual Property-As An Indicator Of A Company's Future Success (Part I), les Nouvelles - Journal of the Licensing Executives Society, Volume LVIII No. 1, March 2023, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4375135
- Markus Dollmann, Dierk-Oliver Kiehne, Andreas Zagos, Ioannis Zagos, Default Risks Of Companies With Valuable Patents, February 2023, http://media.intracomgroup.de/InTraCoM_Defaultrates_20230224.pdf
- Andreas Zagos, Stelian Brad; Using Bibliometric Indicators from Patent Portfolio Valuation as Value Factor for Generating Smart Beta Products, International conference on Modern Management based on Big Data (MMBD2020), Oct. 18th-21st, 2020, http://media.intracomgroup.de/Zagos-Brad2020_Chapter_UsingBibliometricIndicatorsFro
- Andreas Zagos, Stelian Brad; Quantifying sustainable patents for enhancing ESG factors using bibliometric indicators from patent portfolio valuation, Etria world conference TRIZ·18.Okt.2020,http://wumm.uni-leipzig.de/conferences.php?conference=http://wumm.uni-leipzig.de/rdf/TRIZ-Future-2020.rdf
- Andreas Zagos, Stelian Brad; IMPROVEMENTS IN PATENT PORTFOLIO VALUATION WITH BIBLIOMETRIC INDICATORS, 2nd International Conference on Quality and Innovation in Engineering and Management 2, 2 th – 24 th of November 2012, Cluj-Napoca,Romania, http://media.intracomgroup.de/ImprovementsPatentPortfolioValuation05_10_12.pdf

- Andreas Zagos, Stelian Brad, Empirical Study Of The Importance Of Bibliometric Indicators For Patent Portfolio Valuation, 2014 International Conference on Production Research – Africa, Europe and Middle East, 3rd International Conference on Quality and Innovation in Engineering and Management, http://media.intracomgroup.de/EmpiricalStudyImportanceOfIndicators_03_2014.pdf

1.5 Media

- https://www.nasdaq.com/videos/the-patent-value-factor-to-designing-an-index
- https://www.youtube.com/watch?v=OofI3RATlnQ
- https://www.brn-ag.de/41195

Chapter 02: Literature review

2.1 General overview of valuation approaches

Most of the valuation approaches that are also mentioned in Norms are not made for patent valuations basically. Some valuation methods are derived from company valuation (i.e. income approach) or accounting rules (i.e cost approach). This leads to problems in applying the methods to all patents. Also, different approaches may lead to completely different results for the same patent. This makes this topic complex and therefore different methodologies are currently co-existing. In the last decades many theoretical methods have been developed for the evaluation of patents, like

- Model of Hoffman/Barney (Hoffman and Barney, 2002)
- Portfolio model of Hofinger (Hofinger, 1999)
- Cost based Model (Smith and Parr, 2004)
- Income Approach or Discounted cash flow method (Auge-Dickhut et al., 2001)
- Incremental Cash Flow method (Parr, 1988)
- License Analogy Method (Rings, 2000)
- Relief-from-Royalty method (Lee, 2002)
- Real options method (Pakes, 1984)
- Proprietary systems for the evaluation of patents have been developed, which combine different methods (Hagelin, 2003).

In Real estate appraisal there are three basic valuation models, the Cost Approach, the Market Approach and the Income Approach. The same models can be used to valuate intellectual property, especially patents. Each model also has different valuation methods which can be used separately or additional to each other.

2.2 Cost Approach

Regarding the cost-approach the patents' value is equal to the costs for the patent-related R&D costs. This fundamental idea is the core element of all cost-approaches. There are several variations of cost-approaches like discounting the amount of costs by using e.g. the rate of inflation or taking a look at the replacement costs.

2.2.1 Cost approach Usage

Accounting and Book-keeping. Can also be used as a supplement to income approach.

2.2.2 Advantages of Cost approach

Inclusion of IP in company's accounting books.

2.2.3 Disadvantages

A cost-approach is especially useful for operation management and controlling. It's not as useful for financial transactions, because the costs are too high, so that the patents' value is overestimated or the amount of cost is too low, so that the patents' value is underestimated. Further, at the end of a patent`s lifetime the value is maximal, based on this approach and the costs are not proportional to inventive success.

2.2.4 Replacement Costs

The Replacement Costs (Replacement Values) are the costs which were needed to replace an asset at the moment. This includes the development costs, but excludes the costs of failed prototypes.

2.2.5 Recreation Costs

The Recreation Costs are the amount of money which would be needed at the moment, to develop the patent in exactly the same way and the same final state as it currently exists. This includes costs of any prototypes.

2.2.6 Historical Costs

The Historical Costs are the real costs of development of the Intellectual Property, at the time it has been developed. For an accurate analysis there have to be included the inflation and the changes of technology.

2.2.7 Avoided Costs

"Avoided Cost" is essentially the marginal cost for a public utility to produce one more unit of power. Because QFs reduce the utility's need to produce this additional power themselves, the price utilities pay for QF power has been set to the avoided, or marginal, cost. In California, the utilities' avoided costs are determined by the California Public Utilities Commission (CPUC) in public hearings. These prices are designed to simulate a "market price" for energy, and have helped make utilities more efficient in their operations.

2.3 Market Approach

In the economic society it is well known that a market-value is always the most reliable and robust value for every kind of asset. It shows what the buyer is willing to pay for the asset and what the seller wants to receive at the same time. So the general idea is to find a similar patent that has already been priced and traded. The actual value/price is differentiated out of historical transactions. But with this approach there are two major problems: First it is not that easy to gather data of patents which are already priced and traded. Second every Patent is unique and only a few are at least a little similar.

2.3.1 Transaction-oriented

Transaction-oriented approach observes the frequency of transactions and the revenue increase due to IPR to determine the patent value

2.3.2 Price-oriented

Price oriented approach determines the patent value by similar comparable IP or similar transactions.

2.3.3 License-based

Royalty rate-oriented approach determines the value by comparison of the subject IP with royalty rates in similar license agreements.

2.3.4 Market Approach Usage

- To determine the market value of any particular IP.
- Determine the comparable royalty rates for licensing the IP.
- Advantages of Market approach:
- Quite straightforward valuation method.
- Disadvantages of Market approach:
- Every patent is novel and unique. Thus, uniqueness makes direct comparison difficult.
- Comparing a subject IP with a traded IP that has still not been utilized to the full extent possible, has a possibility of subject IP undervalued.
- Limited formal markets for IP (unlike Shares/Stocks).
- Relevant pricing information of the transacted IP is not in public domain.
- Difficult to collate information of the IP that are already priced and traded.

2.4 Income Approach

Regarding the income-approach the patent's value is equal to the amount of the future revenues the patent-holder is going to earn by using his patent. By discounting these patent-related revenues on the valuation date the present value can be calculated. The resulting present value is considered as the patent's value.

The use of the income-approach has two challenges: First the need to have a large database for a reliable outlook on the future revenues for the patent's lifetime. The second major problem is that there is a need to know exactly which part of the products' revenue is related to the monopoly right of a specific patent. In some industries like the pharmaceutical sector this might be easy: There is one active ingredient of a product having one certain market protected by one patent. But when it comes to automotive industries things look pretty different: To find a "one-to-one"-relationship between a patent, a product and a certain value in most cases is impossible.

The need for reliable data makes an income-approach-patent-valuation in most cases quite expensive and -depending on the data's source- subjective. Therefore, the income-approach is not that useful for financial transactions especially the valuation of collaterals. But e.g. for equity investors who are interested in their (future) return on investment (ROI) an income-approach might deliver the information needed and therefore the "right" value.

There are several variations of income-approaches like the real-options- approach. But in general problems and benefits delivered are the same as discussed above for the “simple” discounted-cash-flow-approach.

2.4.1 Income approach Usage

Income approaches are accurate when the following parameters while valuating the patent are properly estimated:

- An income either from product sales or license of the IP
- Duration of IP’s useful life
- IP specific risk factors
- Valid discount rate

2.4.2 Advantages of Income approach

- Relatively simple to determine the value.
- Most parameters can be obtained from the financial statements of the firm and market information.
- The process is fully transparent and allows for various scenarios.
- Revenue forecasting is easier if the patent is already in use.
- The approach has high acceptance and complies with standards.

2.4.3 Disadvantages of Income approach

- Estimating the future cash flows is subjective and may lead to erroneous results thus undervaluing or overvaluing the IP.
- Additionally, it is crucial to know the share of the patent in the product, which becomes complicated if a product contains multiple patents.
- Indirect revenues, such as those from blocking patents, are hard to evaluate, and there is uncertainty about the future.
- Transferring patents to another owner is challenging, and the process is both expensive and time-consuming.

2.4.4 Discounted Cash Flow - Method

The discounted cash flow approach attempts to determine the value of the IPR by computing the present value of cash flows, attributable to that piece of IP, over the useful life of the asset (Darden, University of Virginia). Discount Cash Flow (DCF) method calculates the present value of an IP's future cash flows in order to arrive at a current fair value estimate for the IP.

$$DCF = CF_1/ (1+r)^{1} + CF_2/ (1+r)^{2} + CF_3/ (1+r)^{3} + \ldots\ldots\ldots\ldots\ldots\ldots.. + CF_n/ (1+r)^{n}$$

Where,

- CF_1 = cash flow in period 1
- CF_2 = cash flow in period 2
- CF_3 = cash flow in period 3
- r = discount rate
- n = time frame of the patent (generally 20 years)

2.4.4.1 Factors to be considered in a DCF calculation

- Time value of money
- Riskiness of the estimated future cash flows

2.4.5 Incremental Cash Flow - Method

- By this method the Deposit surplus wasn't determined directly.
- The main question is: Which income can the evaluation object attain without the patent?

2.4.6 Relief from Royalty – Method (licence-price-analogy)

The relief from royalty method is the most established patent valuation method which combines the market approach and the income approach method.

- In this method, the evaluation takes place based on the fact that how much money could be saved by a patent holder, if he owns the patent and doesn't need to rent or license it from a third party.

- Market approach is used to determine comparable information about other traded and priced patents.
- Besides royalty rate, sales forecast is required in order to estimate the income that flows directly from the IP.
- Value using Relief from Royalty can be achieved as follows:
- Determination of royalty rate
- Determining cash flow of patent property
- Saved royalty rates minus tax

2.5 Real Options - Method

Options, in general, are a part of larger class of financial instruments known as derivatives. However, the scope is not limited to finance and can be used for valuation of IP. The basic definition of an option is a right but not an obligation, at or before some specified time, to purchase or sell an underlying asset whose price is subject to some form of random variation (Pitkethly, 1997). The development and commercialization of IP is treated as options. The Real Option Method values these items using the Black-Scholes- or the binomial- approach.

2.5.1 Binominal-Approach

- This is a numeric method for a risk neutral valuation.

2.5.2 Black-Scholes-Approach (Continuous time)

This is a Border Case of the Binominal-Approach. There have to be multiple assumptions which constrict the applicability of the method:

- Underlying Asset Value (Present Value of future cash flow)
- Exercise Price (Present value of costs that must be invested to use the patent)
- Time (Time until patent expires)
- Volatility (Deviation of the growth rate)
- Risk-free rate (interest rate for risk-free investment)
- Dividends (Reduction of options duration due to lose of market shares, market skimming, competitive actions, delays)

2.5.3 Real Options Usage

- The Real Options method are used in the following circumstances:
- Degree of uncertainty is high
- Lack of information at a particular time
- Biotechnology and pharmaceutical industries
- Early stage of IP developments

2.5.4 Advantages

- Values the stream of cash flow along with various other parameters.

2.5.5 Disadvantage

- Complex model
- Difficult to understand and costly evaluation
- Over value IP through inclusion of non-feasible development and decisions

2.6 Other

2.6.1 Model Hoffmann/Barney

The model of Hoffmann/Barney makes use of the patent fees to be paid annually as an indicator of patent value. Basis of this valuation is the relationship between the level of principle of possible patent values and the probability of producing it occurs. Starting point of this model is the renewal of payable U.S. patent fees. The Problem is that individual patent decision makers will (on average) choose to pay maintenance fees only when the perceived value of the expected remaining economic benefit secured by the patent exceeds the amount of the maintenance fee, taking into account appropriate risk factors, anticipated rates of return, etc.

2.6.2 Bibliographic Approach

Bibliographic data can be defined as document identification data. For a patent, particularly, Publication Date, Application Date, Priority Date, Assignee, Inventor, Citing Patents, Cited Patents etc. are some of the bibliographic data. A patent is evaluated based on these data. The method is suitable for evaluating a single patent.

2.6.3 Portfolio Approach

The portfolio approach utilizes the investor's valuations for determining the value of the patents. The investor's valuations could be stock market value or venture capitalists' valuations. The method is suitable for evaluating a firm's patent portfolio.

2.6.4 Scenario weighted Patent-Portfolio-Evaluation-Model

- Model generated by Ernst & Young.

2.7 Standards in patent valuation

2.7.1 SIGNO (2010, German Ministry of Economics)

- First attempt to standardize the procedure of IP valuation
- Focus on the required content in an expertise: valuation scope, date, Assignee, Legal, Technical and Market aspects
- Value determination based on income approach using license analogy. Calculation formula provided

2.7.2 DIN 77100 (2011, Germany)

- Very similar to SIGNO Standard, more detailed and more academic, less practical
- Different valuation methods are theoretically described: income-based approaches, market analogy approach, cost approach. No direct calculation formula provided

2.7.3 OeNorm 6801 (2011, Austria)

- Covers qualitative and quantitative valuation of patents
- Quantitative (monetary) analysis must be done with income approach, Market analogy approach or cost approach
- Very detailed in terms of „how-to ". Calculation formula provided

2.7.4 OECD (2013)

- Qualitative valuation of patents using indicators

- Introduction of different significant indicators based on available electronic data

2.7.5 IFRS - Market approach - Valuation of intangibles (IAS38)

- Primary method under IFRS 3 “Quoted market prices in an active market provide the most reliable estimate of fair value” IAS38.39 If no market exists, fair value could be based on similar arm’s length transactions.
- Quoted market prices in an active market typically provide the most reliable estimate for the value of an asset.
- Only if the prerequisites of the market approach are not fulfilled, the income approach is applied. The cost approach is applied only if the prerequisites of neither the market nor the income approach can be met.

2.8 Analysis of bibliometric data

For this work the analysis of bibliometric data is the most important method. The indicators build from bibliographical data which were analyzed in the past are:

- 2.8.1 The size of the Patent family
- 2.8.2 Forward-/Backward-Citations
- 2.8.3 Number of inventors
- 2.8.4 Accelerated Examination Request
- 2.8.5 Claims

2.8.1 Size of a patent family

Putnam, (1996) and subsequently a number of authors have argued out that information on family size may be particularly well suited as an indicator of the value of patent rights. The studies by Putnam, (1996) and Lanjouw et al., (1998) have shown that the size of a patent family, measured as the number of jurisdictions in which a patent grant has been sought are highly correlated. To measure the potential power of a “family size”, it is recommended to obtained the number of nations in which protection for a particular invention was sought from Derwent’s World Patent Index (WPI) database.

The size of a patent family is an indicator for the market impact that the technology described in the patent may have. The assumption is, that the higher the applicants willingness to pay for a large territory protection, the higher the patents value (Lanjouw et al., 1998).

Recent research has demonstrated that the weighted size of a patent family can effectively predict patent life and the number of citations. This predictive ability is attributed to the tendency of inventors to seek greater international coverage for their more valuable patents (Kabore & Park, 2019). Additionally, the size of a patent family and the inclusion of non-patent backward citations significantly influence the survival duration of patents (Hwang et al., 2021).

Patent family size is a critical indicator used to identify technological innovation, with larger patent families more likely to be commercialized. This correlation underscores the utility of family size as a proxy for patent value (Svensson, 2020). The structure and size of international patent families are also significant indicators of patent value, reflecting both the strategic patenting behaviors of innovators and the economic value of the patents themselves (Dechezleprêtre et al., 2017).

Moreover, patent family size, along with other indicators, assists in estimating the export value of countries by technology fields, showing a robust correlation between patenting activities and economic success (Frietsch et al., 2014). The quality of scientific contributions referenced in patents strongly impacts the commercial value of inventions derived from these patents, indicating the significance of high-quality science in patent valuation (Poege et al., 2019).

Triadic patent families, particularly those with a higher share of USPTO, EPO, and JPO patents and a shorter time span between the earliest and latest priority applications, tend to have higher patent value (Tahmooresnejad & Beaudry, 2018). Additionally, academic patents are valued higher when they have a larger patent family size, highlighting the importance of broad protection in academic innovation (Pereira & Leitão, 2013).

Finally, patent family size and the number of claims positively impact patent values, while factors such as the number of inventors, renewal fees, patent age, and application year have negative effects. Forward citations also show persistent learning effects, reinforcing their role as a valuable indicator of patent value (Og et al., 2020).

On the other hand, some authors claim, that the assumption that patent value increases with its family size is sometimes wrong, because a large number of countries may reflect a lack of maturity of the applicant. Further the larger a potential market for a patent, the higher the likelihood of the focal patent being an incremental contribution and therefore of low technology quality (Van Pottelsberghe and van Zeebroeck, 2008). The main conclusion of several empirical studies is, that the size of a patent family does not reflect linearly the value of patents (Guellec and de la Potterie, 2000).

The size of a patent family is a critical determinant of patent value and quality. Larger patent families, especially those with extensive international coverage, are indicative of higher-value patents. This relationship is supported by various methodologies and indicators, highlighting the strategic importance of patent family management in fostering innovation and achieving economic success.

2.8.2 Forward-/Backward-citations

There are 2 different types of citation: forward and backward citations. Future citations received by a patent (forward citations) are more important than the backward citations, because in the case of forward citation the main indication is, that an innovation has contributed to the development of subsequent inventions. For this reason, citations have been used as a measure of the value of an invention. The main thesis is, that the more often a patent a focal patent is quoted as prior art during examinations of subsequent patent examinations, the more fundamental its technological contribution to the field, the higher the quality (Trajtenberg, 1990a).

Backward citations are used to determine the inventory step of the innovation and because this is connected with the patent applying process of the attorney it can’t be used as good indicator. Some attorneys are using a huge amount of backward citations with the aim to show the examiner that the applied patent is very innovative, other attorneys do not use this very intensively. Also, the application process in different countries lead to different amounts of backward citations. International patent attorneys claim from their experience that the citation ratio is Germany: Japan: US - 1:7:20 – this means that in US they cite 20 times more than in Germany. Further Michel and Bettels, (2001) found that, while 90% citations ins USPTO patents are to other USPTO patents, in EPO patents contain a wide range of patent offices: 23.3% EPO, 30.9% USPTO, 16.3% WIPO, 13.1% Germany, 6.2% British, 5.2% Japanese, and 5% others.

Further the examiners in the Patent offices have a certain amount of Patents they always use for Citations (because of time reduction for the examination process) – this behaviour from the practical point of view can have influences (Criscuolo and Verspagen, 2008).

Further the cited documents can be also used as an indicator. Usually there are other patents or utility models cited but also NPL (Non-Patent-Literature) (Carpenter et al., 1980). The main conclusion is, that the closer a patent application is to “fundamental research”, as reflected by the non-patent references, the higher its technological quality. NPL is also used like backward citation to show the examiner that the state of the art has been approved before applying.

The forward citation is also a main indicator for the litigation process. In the work of Lanjouw and Schankerman, (2001) it is shown that there is a direct impact between citation and litigation. The citation behaviour is also related to the technological field the patent is applied for. Criscuolo and Verspagen, (2008) claim that the share of inventors is also related to the technological field as follows:

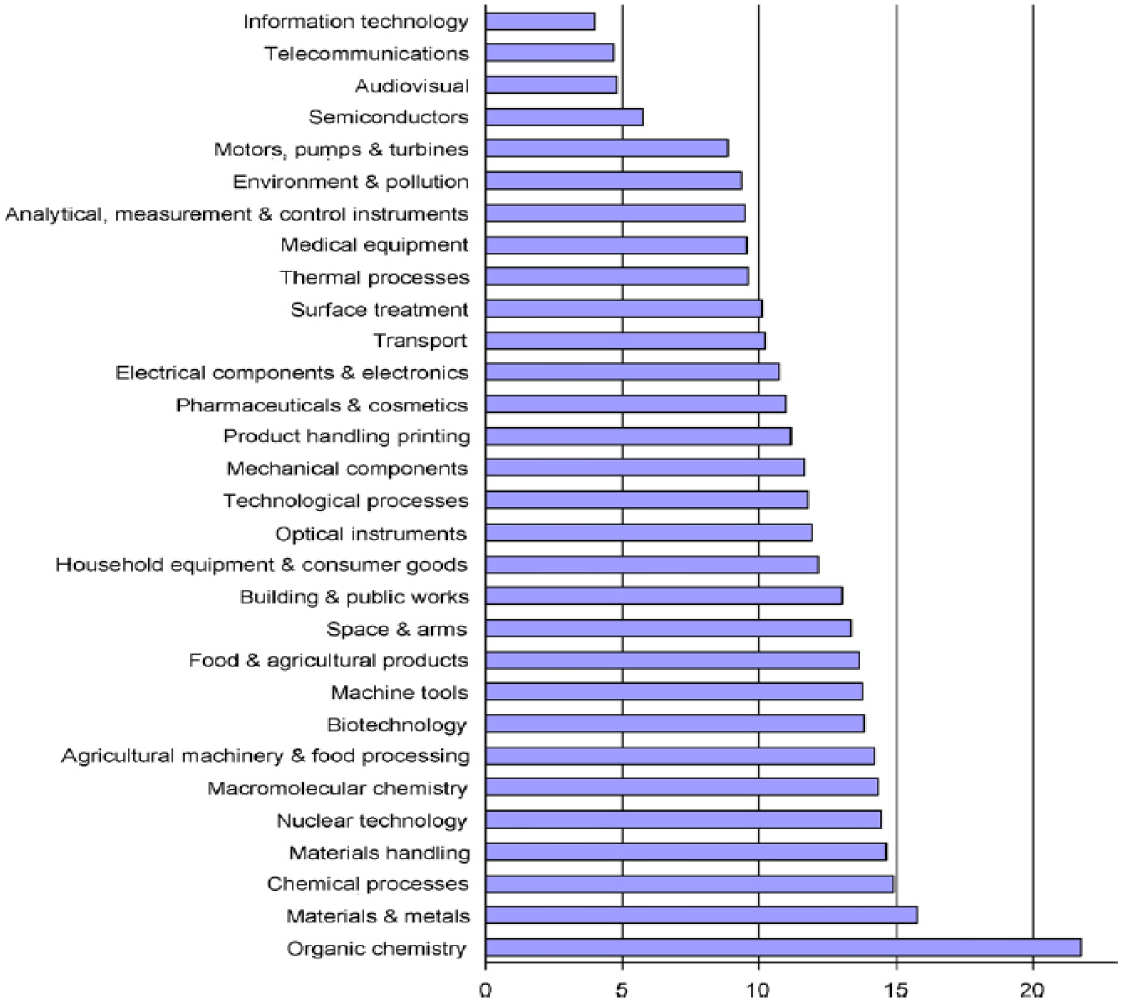


Figure. 1. Share of inventor citations by technological field (Michel and Bettels, 2001).

These results are confirmed by (Sampat, 2004). Examining patent examination: an analysis of examiner and applicant generated prior art].

As shown already, forward citations significantly positively correlate with the pricing of patents, accounting for a significant portion of the variation in the patent prices. They moderately correlate with the commercialization and successful innovation of patents, indicating their utility in identifying valuable patents. On the other hand, forward citations have been viewed as indicators of the economic value of a patent in the sense that patents that are well substantively used in patent office rejections have been found in solid association with private value measurements like patent renewal and litigation (Cotropia & Schwartz, 2018). Forward citations significantly predict the auction prices of patents, reflecting the underlying economic value of the patents sold at auctions (Odasso et al., 2015). It can also be used to forecast the diffusion of emerging technologies, emphasizing the rate of technological innovation in various fields such as biotechnology, telecommunications, and alternative energy (Fallah et al., 2009). Many forward citation-based measures are taken to measure the technological impact of patents, having a great application in the area of intellectual property analytics (Aristodemou & Tietze, 2018). Backward citations are believed to be a positive factor that influences the value of patents, at least within pharmaceutical patents, along with other factors like family size and the number of claims. Indicators associated with citations are said to be of utmost importance in studies on patent valuation. In the biotechnology sector, backward citations were also positively related to present value estimations of firms. So, one may read the provided information indicating that the role of citations may be different in other technological fields (og et al., 2020, Nikulainen et al., 2008).

Forward citations are indicative of the technological impact of patents. Highly cited patents are associated with significant technological advancements and have a higher market value (Aristodemou & Tietze, 2018). They accumulate over time and correlate with a patent's technological impact, indicating important technological advancements. Forward citations also serve as reliable measures of patent quality, correlating with technological improvements and the inventive step size in fields like hybrid corn (Moser et al., 2016).

Patent citations carry both legal and technological implications. Incorporating both dimensions in citation analysis provides a more comprehensive valuation of patents (Wang et al., 2014). Different types of forward citations, such as blocking citations, can indicate higher economic value compared to non-blocking citations, making it crucial to distinguish between citation types for accurate patent valuation (Czarnitzki et al., 2011). The structural properties of forward patent citation networks are essential for accurate patent valuation, with different industries showing varying relationships between citations and patent price (Suh, 2015).

Forward and backward citations are critical indicators of patent value and quality. While forward citations generally reflect technological impact and economic value, backward citations can also play a significant role in specific fields like biotechnology. Different types of citations and their contexts should be carefully considered to provide accurate patent valuations.

2.8.3 Number of inventors

The main thesis is, that the more inventors participate in the research and development process, the higher the resulting technological quality (Guellec and de la Potterie, 2000).

Recent research employing structural equation modelling has revealed the positive impact of involving multiple inventors, particularly those with strong academic linkages, on the technological value of patents. However, it was observed that the inventors' motives related to monetary gain or promotions did not have a direct effect on patent value (Suzuki, 2011).

A study on European inventors found a positive correlation between the number of inventors and the quantity of patents produced. However, this increase in patent quantity did not directly enhance the average value of the patents (Mariani & Romanelli, 2007). Similarly, research focusing on Italian inventors indicated that patent productivity is significantly higher for those working in teams, especially within large firms. The quality of these patents, assessed through forward citations, claims, and family size, also showed improvement, demonstrating the beneficial effects of collaborative efforts (Schettino et al., 2013).

The analysis of patents from Indian manufacturing firms showed that those produced by larger inventor teams hold higher market value, suggesting that collaborative patenting efforts are perceived more favorably in the market (Singh, 2018). In the pharmaceutical industry, patents involving multiple inventors were associated with higher quality, reflected in higher citation counts and greater technological impact (Chen & Chang, 2010).

A comprehensive study on European patents found that those with more inventors tend to possess higher economic value, as evidenced by the positive correlation between the number of inventors and key patent quality indicators such as citations and claims (Gambardella et al., 2008). Additionally, the relationship between patent quality and value was found to be stronger in discrete innovations compared to cumulative ones, with larger inventor teams consistently producing higher quality patents (Baron & Delcamp, 2010).

In Northern Italy, research indicated that while the total number of patents did not influence SME sales performance, the number of jurisdictions where patent protection was extended had a significant positive impact. This underscores the importance of comprehensive patent protection strategies, often involving multiple inventors, for business success (Agostini et al., 2015). Further, an analysis showed that forward citations and the involvement of multiple inventors in patent applications are strong predictors of economic value across different technology fields, whereas family size had limited predictive power (Frietsch et al., 2014).

A study focusing on patent quality indicators revealed that patents generated by teams with robust academic and industry linkages tend to be of higher quality, highlighting the importance of collaborative efforts (Squicciarini et al., 2013). Metropolitan areas in the U.S. with larger numbers of inventors showed increasing returns in patenting activity, indicating that the presence of more inventors positively correlates with both patent productivity and quality (Bettencourt et al., 2007).

A large-scale matching exercise between patent families and publication records demonstrated that patents referencing high-quality scientific contributions are significantly more valuable, emphasizing the impact of collaborative efforts on producing high-quality patents (Poege et al., 2019). Finally, it has been shown that scientific measures of patent quality, such as forward citations and the number of inventors, serve as useful indicators for investors in assessing the economic merit of a firm's inventive activities (Hirschey & Richardson, 2004).

From the practical point of view, how the innovation process works in a R&D department, the thesis of the author is, that over a certain number of inventors (over 7), the technological quality is reduced, because not patent related circumstances lead to the big number of inventors, but for reason of internal policy. Further there has to be defined as well a ratio between number of inventors and total amount employees (better employees in R&D), because a small and medium sized company for example does not have a big R&D department in opposition to a big corporate. This improved indicator is out of the scope of this work, but could be a starting point for further investigations.

2.8.4 Accelerated Examination Request

The main thesis is, that the higher the applicant’s willingness to pay for accelerated protection, the higher the private value of the patent (Reitzig, 2004). The author’s thesis is, that there is no correlation between accelerated examination process and technological quality of the patent, but other reasons, for example an upcoming trade show which forces a quick movement in protecting IP rights. Further from practical point of view, there are some technology sectors who avoid to file the examination process, because they want to keep the patent "secret", this means that for 7 years after the application the competitors do not know the result of the patent application – if it will be granted or not – and therefore they cant appeal the application – which leads to uncertainness of the competitors how to handle this application. Therefore the author believes, that this indicator is not suitable.

Further, accelerated patent examination frequently results in lower quality patents. Busy examiners, under pressure to process applications quickly, tend to approve patents that may not withstand rigorous scrutiny. Shu, Tian, and Zhan (2020) found that patents granted under accelerated conditions often have fewer future citations and a higher probability of invalidation, which negatively affects the value of firms holding these patents.

Examination speed is a predictor of litigation outcomes. Marco and Miller (2017) demonstrated that patents approved through faster examinations are more likely to be of lower quality and, consequently, more prone to litigation. This correlation suggests that the rush to grant patents can compromise thoroughness and accuracy, leading to disputes over patent validity.

Universities that use accelerated examination procedures tend to achieve higher acceptance rates for their patents. According to Kanama (2016), this approach yields substantial benefits, including increased technological realization and higher license income. The ability to quickly secure patent rights enables universities to capitalize on their innovations more effectively.

Increased workloads for examiners, which often lead to accelerated processing, correlate with a decline in examination quality. Kim and Oh (2017) highlighted that heavier workloads result in a greater number of low-quality patents being granted. This trend underscores the need for balanced examiner workloads to maintain high standards in patent approval processes.

The dynamics of patent examination, particularly when expedited, contribute to a cycle where more low-quality patents are granted. Ford (2016) emphasized that accelerated examination processes perpetuate this cycle, ultimately degrading the overall quality of patents.

Patent metrics such as importance and immediacy, which can be influenced by the speed of examination, strongly correlate with technological progress and patent quality. Benson and Magee (2015) demonstrated that high-quality patents are typically those that make significant technological advancements and receive immediate recognition in the form of citations.

The quality of scientific contributions referenced in patents, often influenced by examination speed, is strongly associated with the commercial value of the patents. Poege et al. (2019) found that high-quality references enhance the commercial prospects of patents, suggesting that thorough examination can lead to more valuable intellectual property.

To address the issues stemming from accelerated examination, Atal and Bar (2014) proposed a two-tiered patent system. This system would allow for more thorough examination of high-value patents, thereby improving overall patent quality and reducing the number of low-quality patents. Such a system aims to balance the need for expediency with the imperative of maintaining rigorous examination standards.

Accelerated patent examination has implications for patent quality and firm value. While it offers certain advantages, it often leads to lower quality patents that are more susceptible to invalidation and litigation.

2.8.5 Claims

For the claims a lot of parameters could have an influence like the number of additional claims, the number of independent claims, the number of dependent claims, the average length of independent claims, the shortest independent claim and the characteristic of the claim (product, method or feature). One important indicator is the additional claims. In the EPO, until 2008 an additional fee of + 50 euro was required for the eleventh and each subsequent claim. In 2008, policy changed with even higher fees: from the sixteenth onwards each additional claim costs the applicant 200 euro. The USPTO charges applicants for each fourth and subsequent independent claim little over 200 US dollars while each dependent claim in excess of 20 will cost 50 US dollars (USPTO, 2009). Therefore, the willingness of applicants to pay the extra fees indicates a higher expected patent value (Jansen, 2009). Therefore, there is a strong positive correlation between additional claims and the technological value of a patent.

The main thesis behind of the length of claims is, that the more elements in a claim, the more limited its scope is. Since additional elements require additional words, fewer words could indicate a wider scope. Further, longer claims make it more difficult to force patent rights, partly because the content of the claim becomes less clear (Jansen, 2009). Therefore there is a negative correlation between the length of claims and the technological value of a patent (Van Pottelsberghe and van Zeebroeck, 2008). The puzzle of patent value indicators (van Zeebroeck, 2009). The thesis for the claim characteristic is that claims related to products have a higher value than those related to methods than those related to features (Jansen, 2009). The basic idea behind that is that the work-around for the product claims is much more difficult than i.e. for a feature.

Empirical research underscores the critical role of patent value indicators, such as the duration of patent renewals and the extent of the patent family, in forecasting commercialization success. Svensson (2020) demonstrates that these indicators are essential in determining patent value, thus highlighting their significance in the broader context of technological innovation.

Amano (2020) investigates the impact of the United States Patent and Trademark Office (USPTO)'s quality-improving initiatives introduced in 2000 on the scope of business method patents. The study reveals an increase in claim length post-initiative, suggesting that longer claim lengths serve as a useful indicator of patent quality.

Marco, Sarnoff, and deGrazia (2016) delve into the metrics for measuring patent scope through claim language, focusing on independent claim length and count. Their findings validate these metrics by showing their explanatory power concerning patent scope correlates, such as maintenance payments and forward citations, emphasizing the importance of claim characteristics in assessing patent value.

Og et al. (2020) analyze patent renewal information and find a positive association between the number of claims and patent values. This underscores the importance of the number of claims as a determinant of patent value, reinforcing the idea that detailed claims contribute significantly to a patent's perceived worth.

Odasso, Scellato, and Ughetto (2015) provide empirical evidence from patent auctions, indicating that the number of claims is positively related to the closing price of patents. This relationship suggests that patents with more claims are perceived as having higher economic value, thus making them more attractive in auction settings.

Dang and Motohashi (2015) explore the role of patent statistics in indicating innovation quality, particularly in the context of China’s patent subsidy programs. They find that metrics such as the number of nouns in claims are meaningful indicators of patent quality and innovation, highlighting the detailed linguistic elements of claims as significant quality markers.

Cotropia and Schwartz (2018) examine patents utilized in office rejections and find that these patents are positively correlated with several measures of private value, including the number of claims. This suggests that patents frequently cited in rejections hold higher value, underlining the importance of claim quantity in determining patent worth.

Benson and Magee (2015) establish a correlation between patent metrics and technological progress. They show that the importance, recency, and immediacy of patents in a specific domain are strongly linked to technological advancement, with the number of claims being a significant contributing factor. This reinforces the role of comprehensive claims in reflecting technological improvements.

Across various studies, common themes emerge regarding the significance of patent claims and related metrics in determining patent value and quality. Whether through the lens of commercialization success, auction pricing, or technological progress, the detailed characteristics of patent claims, such as length and number, consistently appear as crucial indicators. These findings collectively highlight the multifaceted role of patent claims in assessing and driving technological innovation.

2.8.5 Combined indicators

The most research on patent indicators was done based on single metrics like claims, there are only a few research works focussing on multiple indicators for patent value detection or generation.

Fischer and Leidinger (2014) conducted an empirical study leveraging auction data from Ocean Tomo to test the validity of patent value indicators. The study finds strong empirical support for using forward citations and patent family size as reliable indicators of patent value. Their findings underscore the importance of these indicators in predicting the market value of patents.

Kopczewska and Kopyt (2014) propose a methodology introducing non-linear corrections to the traditional market model of patent valuation. This approach considers additional factors such as the time to patent expiration and the risk of copying. The non-linear corrections provide a more nuanced and accurate reflection of patent value, addressing limitations of linear models.

Thoma (2014) develops a composite value index that integrates twenty different patent indicators through factor analysis. This index combines bibliographic and survey datasets to validate the market value of patents. The composite index approach allows for a comprehensive assessment of patent value, incorporating a broad spectrum of indicators.

Trappey et al. (2021) apply deep learning models to estimate the value of IoT technology patents within the manufacturing industry. Utilizing Principal Component Analysis (PCA) and Deep Neural Networks (DNN), the study demonstrates significant improvements in patent valuation accuracy. The integration of deep learning techniques represents a significant advancement in automated patent value estimation.

Lin et al. (2018) presented a deep learning-based model that integrates citation networks and patent text materials to evaluate patent quality. This approach leverages the capabilities of deep learning to process and analyze complex datasets, providing a sophisticated tool for assessing patent quality and, by extension, value.

Xiao-bing (2007) conducted a study that organized patent value indicators into two distinct levels. By analyzing the correlations among these indicators, the study aimed to eliminate redundant calculations and improve the accuracy of patent valuations. This method not only streamlines the valuation process but also ensures a more precise assessment by focusing on unique and impactful indicators.

Che and Huang (2010) explored the assessment of patent values in the context of patent infringement lawsuits. They employed multi-regression analysis and neural networks to construct a valuation model. This model was based on 17 patent indicators, which were analyzed for their influence on damage awards in infringement cases. The integration of neural networks allowed for capturing complex relationships among the indicators, enhancing the model's predictive power.

Pachys (2010) utilized Business Intelligence (BI) tools to analyze data from the United States Patent and Trademark Office (USPTO). The study aimed to refine patent valuation algorithms by incorporating innovative metrics such as Forward Importance Patent (FIP) and Backward Importance Patent (BIP). These new metrics provided a more nuanced understanding of a patent's impact, contributing to more accurate valuation outcomes.

Thoma (2014) proposed a composite value index, integrating twenty different patent indicators. This index combined bibliographic and survey datasets to validate the market value of patents. The composite index offered a holistic view of patent value, incorporating multiple dimensions and ensuring a robust validation against actual market data.

Aristodemou and Tietze (2018) introduced Intellectual Property Analytics (IPA), which employs artificial intelligence, machine learning, and deep learning methods to analyze intellectual property data. IPA reveals relationships, trends, and patterns that assist in better decision-making and the discovery of innovative technologies. This approach highlights the potential of AI-driven analytics in enhancing the understanding and management of intellectual property.

Verhoeven, Bakker, and Veugelers (2015) developed patent-based indicators to measure technological novelty. Their indicators provide a comprehensive assessment of technological advancements, increasing the variance of impact and the likelihood of identifying significant innovations. This methodology emphasizes the importance of novelty in patent valuation, contributing to the identification of groundbreaking technologies.

Lee et al. (2018) proposed a machine learning approach to identify emerging technologies using multiple patent indicators. They extracted 18 input and 3 output indicators from the USPTO database and employed a feed-forward multilayer neural network. This neural network captured complex nonlinear relationships between the indicators, facilitating early and accurate identification of emerging technologies. The study demonstrated the effectiveness of machine learning in recognizing and predicting technological trends.

2.9 Existing indicator-based models for measurement of patent quality

There are professional software solutions in the market existing for measurement of patent quality based on bibliometric indicators. The following table shows the existing products

Table 2.1 A Benchmarking of existing valuation solutions

Company/ Organization	Description	Useful for	Not suitable

IP Business Information B.V. [NL], https://www.ip-bi.com/	IP-BV Software has valuated all patents worldwide. Patent belonging to a same Assignee are evaluated to give a complete portfolio value of a particular assignee. IP-BV software additionally provides the monetary value for the patents. The software analyses 26 automatic bibliographic data and additional up to 75 manual indicators on patent data to deliver qualitative and quantitative valuation results.	Standalone software for all valuation purposes.	
IPR Strategies Ltd., https://www.ipr-strategies.com/ (IRE)	IPR Strategies delivers patent value dataset of public listed companies. Patent values in USD for publicly traded companies worldwide plus additional qualitative metrics including history. ESG and SDG related patent values for publicly traded companies worldwide	Datafeed for Finance sector	
European Patent Office (EP), https://www.epo.org	European Patent Office (EPO) has a product named IP Score which was developed by Danish Patent Office. IP Score takes 40 assessment factors and gives a numerical rating between 1 and 5 where 1 being the minimum and 5 being the maximum. IP Score provides a radar chart for comparison between different patents.	IP Score is beneficial for self-assessment of existing patents.	Monetary rating for all financial purposes.
Korean Patent office (KR), https://www.kipo.go.kr/	Korean Patent Office uses some bibliometric indicators for patent valuation – no transparency which are used and how the value calculation is done (no transactions available)	Korean development bank for securing loans	Not suitable for all types IP Valuation. Non-transparent method of valuation
Ocean Tomo (US), https://oceantomo.com/	Ocean Tomo Ratings system provides patent data, ratings and analysis platform for patent quality, competition and competitive trends, and relevant technologies. Ocean Tomo's patent based indexes are based on the above developed indicators. The ranking system is based on owner's willingness to pay patent maintenance fees.	Ocean Tomo Ratings system can be used for benchmarking of corporates for their patent strength.	Monetary rating

Innography (US), https://clarivate.com	Innography's PatentStrength valuates patents based on the assumption whether the patent will be litigated or not. PatentStrength can be used for finding the Highest value Patents, quickly Assessing the Patent portfolios and determining the Relative Strength. CustomStrength is another tool from Innography which allows creating own weightings and metrics for patent valuation.	Highest Value Patents, relative strength and benchmarking	Monetary Rating
Questel (FR), https://www.questel.com	Questel's Orbit provides a qualitative rating for bibliometric indicators of a particular patent.	Questel's Orbit provides patent search along with Patent valuation	Monetary Ratings.
Lexis-Nexis (US), https://www.lexisnexis.co.uk/	Lexis Nexis provides an analytics platform allowing flexible analysis capabilities. Lexis Nexis uses 3 bibliometric indicators for qualitative rating.	Can be used for benchmarking, portfolio management, licensing, M&A, trends and R&D strategy.	Monetary rating
ToolIP (ES), https://www.toolipvaluation.com/	ToolIP utilizes patent risk and opportunity effects on the popularly known income models to calculate the patent valuation	Valuation for royalty rate calculation or for license dealing.	Monetary rating

2.10 State of the art in asset management research

To assess the impact of intellectual property rights, researchers in the scientific community frequently investigate the positive correlations between patent value and stock price. This entails analyzing whether securities associated with valuable patents exhibit superior market performance. The measure of the market performance includes various indicators such as increase in market capitalization or dividend payments. The effects should establish the fact that, strong intellectual property rights as indicated by high value patents, correspond to improved financial outcomes by the companies holding those patents.

The following research works show positive correlations:

- Patent quality, in particular measured by forward citations, are strongly correlated with export strength of a company, Frietsch 2014.
- Patent quality, in particular measured by forward citations, are strongly correlated with firm market value, backtested in US smartphone industry and biotechnology industry, Suh 2015.
- Intellectual property protection has a significant positive impact on enterprise value, and R&D investment is the mediating variable between intellectual property protection and enterprise value, Liu 2023.
- Intellectual property rights is an important source of an organization's economic wealth and is linked to a firms performance, Bollen 2005.
- Software patent stocks positively affect the relationship between a firm's open source software product portfolio and its value, Aksoy-yurdagul 2015.
- Positive relationship between the size of patent portfolios, measured by forward citations and credit ratings of companies, Carl Benedikt Frey 2020.
- Patent activity significantly impacts stock price movements and essential statistical characteristics of drift and volatility in the high-tech sector, Vitt 2015.

While numerous research studies have demonstrated positive correlations between patenting activity and company value, none have provided definitive quantitative results to substantiate this relationship. This current study is the first to empirically validate this theory using quantitative measures.

Chapter 03: Data and methodology

3.1 Empirical study

An empirical study was performed during 2013 among 40 experts in IP valuation. Most of the experts operate in the industrial area, the participants profession is characterized as follows:

Sector	No. of experts
Technology	19
Aerospace and defence	2
Communications	2
Energy & utilities	2
Engineering	2
Retail	2
Chemicals	1
Government	1
Healthcare	1
Industrial manufacturing	1
Pharmaceutical	1
Not specified	4

At the study different theories for the bibliometric analysis of patents were examined. The first area is the size and country of the granted patent family members. Putnam, (1996) and subsequently a number of other authors argued that information about patent family size may be particularly adapted as value indicator for patent rights. The studies by Putnam, (1996) and Lanjouw et al., (1998) [uniformity in citations] have shown that the size of a patent family, measured as the number of jurisdictions (patent countries) in which a patent grant has been sought, are highly correlated.

To measure the strength and intensity of the of the “family size” indicator, it is recommended to verify the number of countries in which protection for a particular invention was sought. The size of a patent family is an indicator for the market impact that the technology described in the patent may have. The assumption is, that the higher the applicants willingness to pay for a large territory protection, the higher the patents value.

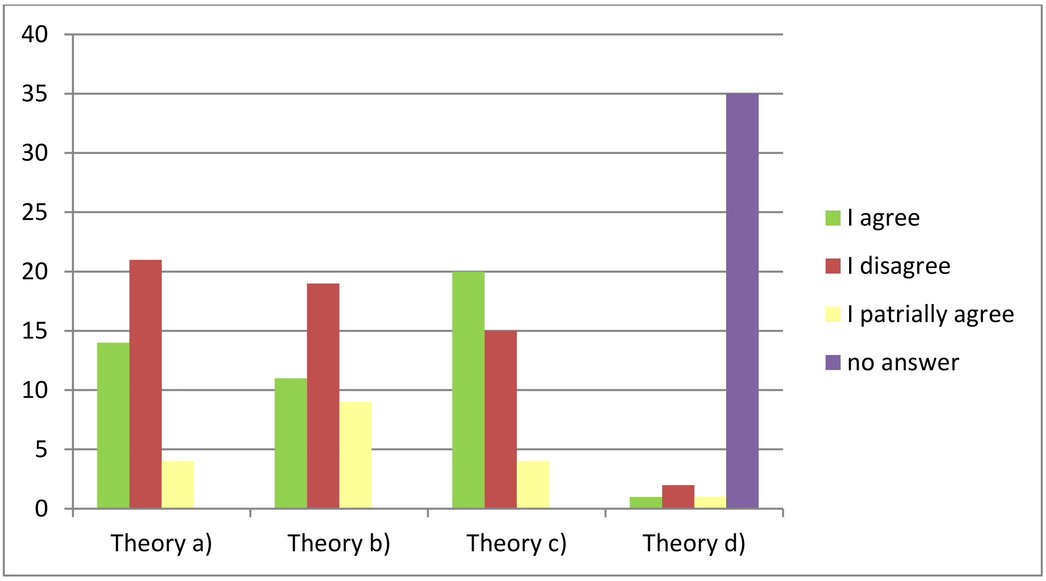
On the other hand some authors claim, that the assumption that patent value increases with its family size is sometimes wrong, because a large number of countries may reflect a lack of maturity of the applicant. Further the larger a potential market for a patent, the higher the likelihood of the focal patent being an incremental contribution and therefore low technology quality (Burke and Reitzig, 2007). The main conclusion of several empirical studies is, that the size of a patent family does not reflect the value of patents in a linear way (Guellec and de la Potterie, 2000).

In addition to that the patent family in a company has very often the same designated states. This occurs from the specific technology in the specific countries a company is active, but one influence factor is also the force of habit in the IPR department.

The following theories were examined in the current study:

- The larger the family, the higher the market impact
- A granted us patent is always more valuable than any other
- A triade patent family (US, EP, JP) always has the highest value
- Size and country of the granted patent family members

The results of the answers are shown at the following graph:



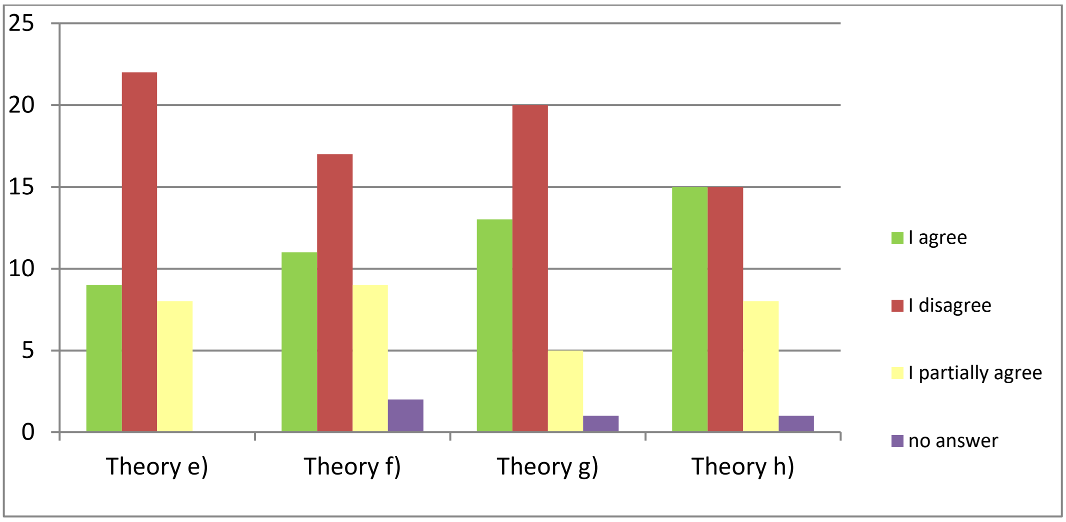
The answers of the experts' rating reflect clear opposing opinions about the impact of a patent family. Therefore, there is a need in adjusting this indicator and turning him into a particular significant indicator by interpreting the technology described in the patent family and connecting it with the GDP of the specific country. The second area examined at the study are the citations in a patent. There are two different types of citation: forward and backward citations. Forward and backward citation are Future citations received by a patent (forward citations) and are more important than the backward citations, because in the case of forward citation the main indication is, that an innovation has contributed to the development of subsequent inventions. For this reason, citations have been used as a measure of the value of an invention. The main thesis is, that the more often a patent a focal patent is quoted as prior art during examinations of subsequent patent examinations, the more fundamental its technological contribution to the field, the higher the quality (van Zeebroeck, 2009).

Backward citations are used to determine the inventory step of the innovation and because this is connected with the patent applying process of the attorney it can't be used as good indicator. Some attorneys are using a huge number of backward citations with the aim to show the examiner that the applied patent is very innovative, other attorneys do not use this very intensively. Also, the application process in different countries leads to different amounts of backward citations. International patent attorneys claim from their experience that the citation ratio is Germany: Japan: US is 1:7:20 – this means that in US they cite 20 times more than in Germany. Further Michel and Bettels, (2001) found that, while 90% citations ins USPTO patents are to other USPTO patents, in EPO patents contain a wide range of patent offices: 23.3% EPO, 30.9% USPTO, 16.3% WIPO, 13.1% Germany, 6.2% British, 5.2% Japanese, and 5% others. Further the examiners in the Patent offices have a certain number of Patents they always use for Citations (because of time reduction for the examination process) – this

The following theories were examined in the current study:

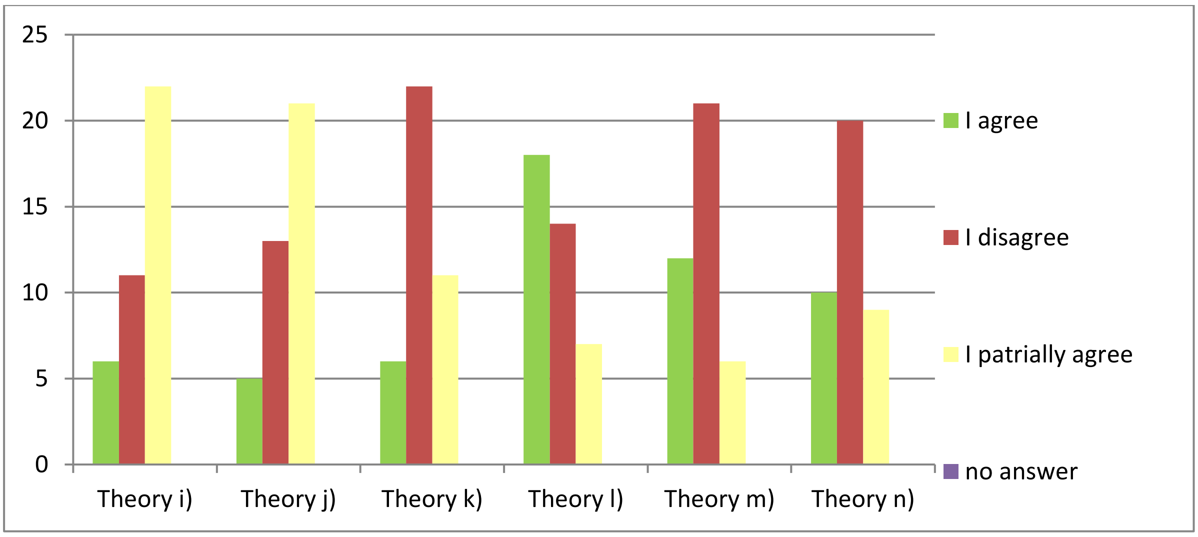
- The more backward citations found in a patent, the better the state of the art described
- The self- citations of an assignee do not count when calculating the citation index
- The more foreign forward citations, the higher the technology impact of the patent
- Citations are correlated with patent age (e.g. A young patent can't have forward citations)

The answers of the experts' rating reflect as well clear opposing opinions with a negative trend for this indicator. Therefore, there is a need for improving this indicator and to take different factors like the increasing numbers of citations in the last years, the citations of the examiners etc. into the consideration.



The third area examined at the study are different other theories:

- Number of applicants, optimum 1
- Number of inventors, optimum at 3-7
- Accelerated examination request
- Number of independent claims (the more the better)
- Length of claims (the shorter the better)
- Patent age – optimally around 11 years



The answers of the experts' rating reflect in this area opposing opinions as well, but some theories are more mainstream.

3.2 Improvement of indicators

Based on different possible indicators, the proposed main indicators determining the market and technology impact of patents are basically:

Market Impact [Mi] = *f* (size of the patent family)

Technology Impact [Ti] = *f* (citations)

Assignee impact [Ai] = *f* (alive patent families, employees and total assets of the assignee)

Market impact [Mi]

The proof of principle relying on the use of patent families as substantive market indicator is supported by following thesis:

> *The larger a strict patent family (count of equivalents), the higher the patent value because more markets are protected by monopole) and the more economically important the countries of patent application in the family are (from a market perspective) the higher the patent value.*

This thesis is as well confirmed from the survey, "Theory c".

The importance of the countries correlates with the dynamic IPC deployment. This means, that e.g. a patent assigned for US is more important than a patent assigned for a third world country. But, there is the possibility that patented technologies address newly industrialized countries or developing countries, e.g. mining- or oil-drilling-technologies.

This indicator was not understood at the survey, therefore "Theory d" had low response.

A number of authors have argued out that information on family size may be particularly well suited as an indicator of the value of patent rights. The studies by Putnam, (1996) and Lanjouw et al., (1998) have shown that the size of a patent family, measured as the number of jurisdictions in which a patent grant has been sought are highly correlated. To measure the potential power of a “family size”, it is recommended to obtained the number of nations in which protection for a particular invention was sought from Derwent’s World Patent Index (WPI) database (Lanjouw et al., 1998). The study from Jaffe and De Rassenfosse, (2019) shows, that there exists as well a bias for the priority application.

The size of a patent family is an indicator for the market impact that the technology described in the patent may have. The assumption is, that the higher the applicant’s willingness to pay for a large territory protection, the higher the patents value (Shepherd and Technology, 2010).

There exist some studies Dou, (2004) showing that triadic patents (patent family applied and/or granted in Europe, Asia and USA) having a higher value then only filed in single countries, but due own experience of the author in several valuation projects the value of a patent depends much more on the certain economy where the patent is filed.

The market impact is therefore defined to the share of the IPC class (distinct 4 digit IPC subclasses) in the certain country where the patent family is filed, expressing the importance of the technology area in the certain country. The market impact is further directly correlated with the economic size of the country (expressed in GDP), the importance of the certain technology in that country (expressed in share of the IPC class in the country) and the legal status of the patent family (application, grant or utility model) (Criscuolo, 2006).

The quality of a family is described as “the share of GDP in the applied country correlated with share of applied country at the same IPC (main) class”. This new indicator is describing more precise the value of the patent family because each patent family is analysed specific to the market importance of the technology at the applied country.

Therefore, the improved indicator is proposed which is

$$[\mathrm{Mi}] = \sum_1^n \frac{number\ patents\ in\ the\ IPC\ class\ in\ the\ country}{total\ number\ of\ patents\ in\ the\ IPC\ class} * \frac{GPR\ of\ the\ country}{Global\ GDP} * Co \qquad (1)$$

- *Co = factor for legal status of the patent family member defined to*
- *Granted patent = 100%*
- *Applied patent = 20 %*
- *Utility model = 10%*

3.3 Technology impact [Ti]

There are 2 different types of citation: forward and backward citations. Future citations received by a patent (forward citations) are more important than the backward citations, because in the case of forward citation (Criscuolo and Verspagen, 2008)the main indication is, that an innovation has contributed to the development of subsequent inventions. For this reason, citations have been used in several studies as a measure of the value of an invention (Van Pottelsberghe and van Zeebroeck, 2008, Carpenter et al., 1980). The main thesis is, that the more often a patent is quoted as prior art during examinations of subsequent patent examinations, the more fundamental its technological contribution to the field, the higher the quality (Trajtenberg, 1990b, Ernst, 2000).

Backward citations are used to determine the inventory step of the innovation and because this is connected with the patent applying process of the attorney it can't be used as good indicator: some attorneys are using a huge number of backward citations with the aim to show the examiner that the applied patent is very innovative, other attorneys do not use this very intensively. Also, the application process in different countries leads to different amounts of backward citations.

The examiners in the Patent offices have a certain number of patents they always use for citations (because of time reduction for the examination process) – this behaviour from the practical point of view can have influences. This topic was examined by Criscuolo and Verspagen, (2008) and Alcacer et al., (2006)].

Further the cited documents can be also used as an indicator. Usually there are other patents or utility models cited but also NPL (Non-Patent-Literature) (Verspagen and Criscuolo, 2005). The main conclusion is, that the closer a patent application is to "fundamental research", as reflected by the non-patent references, the higher its technological quality. NPL is also used like backward citation to show the examiner that the state of the art has been approved before applying.

The forward citation is also a main indicator for the litigation process. In the work of (Lanjouw and Schankerman, 2001) it is shown that there is a direct impact between citation and litigation.

The current Technology impact is defined as follows: the number on foreign citations were divided through the number of alive patents. The normalization was performed under the backward citation index, average per economy (country) (Sampat, 2004).

Self-citations (even intra-corporate from subsidiaries) and references to non-patent literature have been excluded from the count. Approximately 11 percent of all citations in the sample from Jaffe and Tratenberg, 2003 are self-citations. To determine this indicator properly the corporate tree from the company must be available (Jansen, 2009)

The challenge on the using citations as indicator is, that it does not only depend on the quality of a patent but also on the remaining life of the patent: e.g. if a patent is newly published it cannot have any citations, if a patent is quite old, the possibilities are growing.

This thesis is as well confirmed from the survey, “Theory h)”.

The technology impact [Ti] is defined to:

$$[\mathrm{Ti}] = \frac{\text{number on foreign citations (normalized)}}{\text{number on alive patents}} \qquad (2)$$

3.4 Assignee impact [Ai]

The assignee itself seems to have an impact for the value of a patent because he needs high resources to get the patents in force, to block competitors and to sew infringements. One metric to determine the commercial strength of an assignee is the amount on “total assets”. Further the more granted patents a research and development department is producing, the higher the quality of the patents due to standardised processes and intellectual knowledge in patenting.

The total assets are normalized to the maximum of 369.8 B€ on total assets for Toyota Motor Corporation (Nkomo, 2019), having as industrial, non-governmental owned, the worldwide highest total assets declared in the balance sheet.

The Assignee impact is defined to:

$$[\mathrm{Ai}] = \frac{Number\ of\ alive\ patents}{Number\ of\ employees} * \frac{Total\ assets}{Maximum\ total\ assets} \qquad (3)$$

Business data provided from (van Dijk, 2019).

3.5 Total Patent Quality [TPQ]

The calculation of the total patent quality TPQ in %, is based on the equal weighted indicators Ai, Ti, Mi, as:

$$TPQ = Ai \cdot Ti \cdot Mi \qquad (4)$$

3.6 Databases

The used databases for the backtesting and all the following experiments were:

3.6.1 Patent data

The used database for patent data was “Patstat” which is a global database containing bibliographical data relating to more than 100 million patent documents from industrialised and developing countries. It also includes the legal event data from more than 40 patent authorities contained in the EPO worldwide legal event data (EPO, 2020).

3.6.2 Economic data

The economic data used for the experiments was downloaded from the World bank Open Data (Data, 2020).

3.6.3 Business data

Business data have been collected from Moodys product “Orbis”, which is the Bureau van Dijk's flagship company database (van Dijk, 2019). It contains information on companies across the world and focuses on private company information. It has information on around 400 million companies from all countries. The main information which was exported from the database have been: total assets, number of employees, corporate tree with subsidiaries >51% share. For public listed companies business data were collected from Refinitiv (LSEG, 2024). The main information which was exported from the database have been: ISIN identifier, stock quotes of the equities (closing prices), list of constituents for back tested indices.

3.6.4 Patent quality indicators

The patent quality indicators are provided by (Intracom, 2023), who is generating different qualitative and quantitative patent value metrics based on indicators.

3.6.5 Equity research & financial backtests

The equity research and the backtesting of indexes was supported with data and expertise by IPR Strategies (IPR, 2023).

Chapter 04: Contents and results

4.1 Improvement of stock market index

The aim of this experiment is to see, whether there is an improvement in a typical mixed index like STOXX Europe 600 when applying qualitative patent value metrics and comparing the resulting equity selection with the equal weighted index. The underlying data of the experiment are as follows:

4.1.1 Data samples

Table 4.1. Data samples of patent metrics for a sample set of companies from STOXX600

No.	Company name	1	2	3	4	5	6	7
1.	BP PLC	GB	10,264	25,144	81	90	100	51
2.	SIEMENS AG	DE	208,112	297,635	95	87	100	99
3.	HENNES & MAURITZ AB	SE	7	2	31	36	0	56
4.	ASTRAZENECA	GB	42,525	34,160	81	95	100	48
5.	SODEXO	FR	23	19	39	60	0	58
6.	TELEFONAKTIEBO-LAGET	SE	134,219	81,995	91	88	100	85
7.	CREDIT AGRICOLE S.A.	FR	78	84	51	100	54	0
8.	HENKEL AG & CO. KGAA	DE	32,265	28,764	83	94	100	55
9.	WM MORRISON SU-PERMARKETS	GB	5	4	44	63	13	55
10.	ALLIANZ SE	DE	86	80	79	91	100	48

1 Country code; 2 Number of live publications; 3 Number of granted publications; 4 Total patent quality in %; 5 Technical impact; 6 Market impact; 7 Assignee impact

Table 4.2. Data samples of financial metrics for a sample set of companies from STOXX600

No.	Company name	1	2	3	4	5	6	7
1.	BP PLC	GB	GB0007980591	7	5	5	70	262
2.	DAIMLER AG	DE	DE0007100000	76	45	46	298	302
3.	TOTAL S.A.	FR	FR0000120271	57	43	46	107	243
4.	FIAT CHRYSLER	NL	NL0010877643	22	12	13	191	98
5.	BMW	DE	DE0005190003	98	69	71	133	228
6.	NESTLE S.A.	CH	CH0038863350	77	65	71	291	117
7.	SIEMENS AG	DE	DE0007236101	126	100	110	385	150
8.	DEUTSCHE TELEKOM AG	DE	DE0005557508	16	13	15	210	170
9.	ENEL SPA	IT	IT0003128367	5	4	5	69	165
10.	TESCO PLC	GB	GB0008847096	3	2	3	464	57

1 Country code; 2 ISIN number; 3 Market price – high, EUR, year 2018 4 Market price - low, EUR, year 2018; 5 Market price - year end, EUR, year 2018; 6 Number of employees in 1,000; 7 Total assets, b€

The Stoxx600 Index contains in general 20 sectors. The sectors considered for the patent portfolio index are:

- Automobiles & Parts
- Basic Resources Services (Basic resources)
- Chemicals
- Construction Materials
- Food & Beverages
- Industrial Goods
- Media
- Medical Engineering (Healthcare)

- Oil Services, Green Energy (Oil&Gas)
- Personal & Household Goods
- Retail
- Technology
- Travel & Leisure

The sectors not considered (due low IP activity and importance) are:

- Banks
- Basic Resources (producers)
- Financial Services
- Insurance
- Oil & Gas (producers)
- Real Estate
- Real Estate Cap

In the Stoxx600 232 companies were identified having a reasonable number on patents:

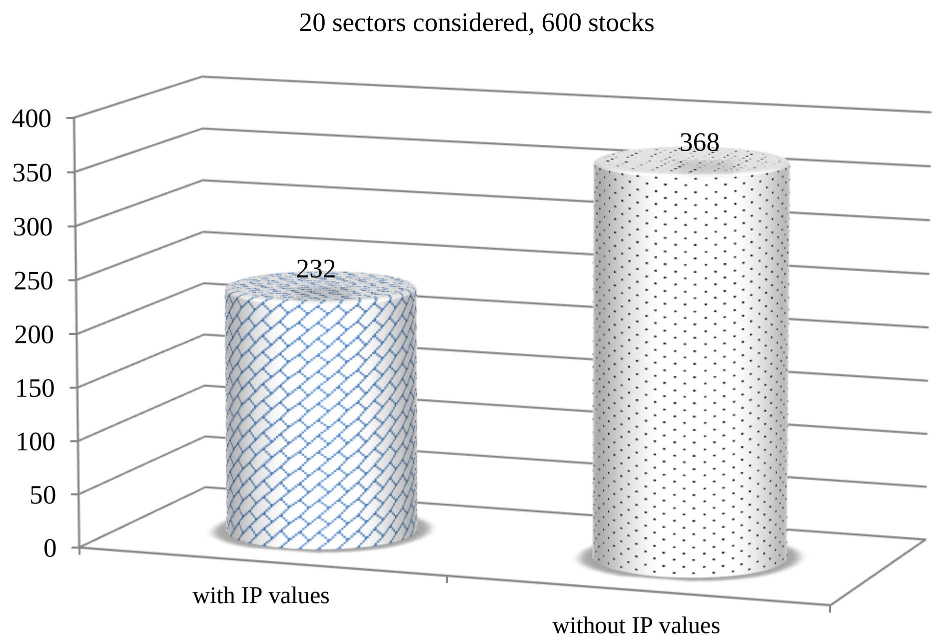


Figure. 2. Number on equities with high quality patents in Stoxx 600 index

In these sectors the equities with highest IP relevance were selected:

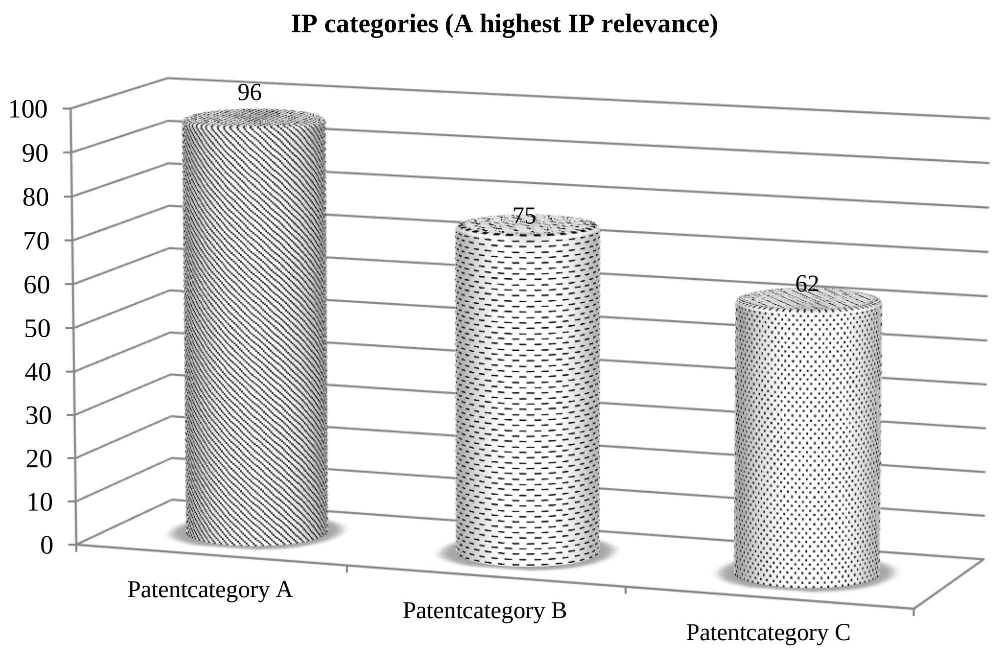


Figure. 3. Categories within the IP value index

The selected equities in the Patent category A in the IP portfolio listed in table 4.3.

Table 4.3. Top equities with highest patent portfolio quality in STOXX600 index

- ABB Ltd.
- Actelion Ltd.
- Air Liquide SA
- Akzo Nobel N.V.
- Alcatel-Lucent SA
- Alstom SA
- Arkema SA
- ARM Holdings plc
- ASML Holding NV
- ASSA ABLOY AB
- Associated British Foods plc
- Atlas Copco AB
- BASF SE
- Bayer AG
- Beiersdorf AG
- BT Group plc
- Carlsberg A/S
- CGG
- Clariant AG
- Compagnie de Saint-Gobain SA
- Michelin SCA
- Continental AG
- Daimler AG
- Danone SA
- Deutsche Lufthansa
- Diageo plc
- Electrolux AB
- Elekta AB
- Essilor International
- FLSmidth & Co.
- Fortum Oyj
- Fresenius Medical
- Fresenius SE & Co.
- GEA Group
- Gemalto N.V.
- Getinge AB
- Givaudan SA
- GKN plc
- Grifols, S.A.
- Henkel AG & Co.
- Hexagon AB
- Infineon
- International Consolidated Airlines
- Investor AB
- Johnson Matthey
- Kone Oyj
- LANXESS AG
- Legrand SA

- LM Ericsson Telefon
- Lonza Group AG
- L'Oreal SA
- Metso Oyj
- Nestle S.A.
- Nokia Oyj
- Novo Nordisk A/S
- Novozymes A/S
- Orange SA
- Outotec Oyj
- Petroleum Geo-Services ASA
- Porsche Automobil
- Prysmian S.p.A.
- Reckitt Benckiser Group plc
- Rolls-Royce
- Royal DSM NV
- Royal KPN NV
- Royal Philips NV
- Safran SA
- Salzgitter AG
- Sandvik AB
- SAP SE
- SBM Offshore NV
- Schneider Electric
- SES SA FDR
- Siemens AG
- SKF AB
- Sky plc
- Smith & Nephew
- Smiths Group Plc
- Solvay SA
- Sonova Holding AG
- STMicroelectronics NV
- SUEZ SA
- Swatch Group Ltd.
- Syngenta AG
- Tate & Lyle PLC
- Technip SA
- Telecom Italia
- Telia Company AB
- UCB S.A.
- Umicore
- Unilever NV Cert. of shs
- Unilever PLC
- Veolia Environnement
- Vestas Wind Systems
- Vivendi SA
- Wartsila Oyj Abp

4.1.2 Results

4.1.2.1 Backtests on STOXX600

The performance of the patent portfolio containing the selected 232 equities with high patent quality was analysed. The portfolio construction was as follows:

The Stoxx Europe 600 Index is separated in stocks with high quality starting at 01.01.2010 until 30.04.2021. The patent stocks are yearly adjusted per 31.07; Benchmark is equal weighted Stoxx Europe 600 Portfolio ("Stoxx Europe 600"; 600 stocks); degree of investment = 100%; no risk management; no fees; ex dividend; all stock prices are calculated in EUR. The first question was how many of the patent stocks should be selected to receive better performance metrics. The metrics for the optimum amount on best patent stocks (from all patent stocks) have been selected as shown in the next table.

The results are compared with the Stoxx600 Index (+109% performance):

Table 4.4. Performance of patent stocks depending on selected share

Share on best patent stocks	Avg 10 Y Return	Sharpe ratio	Volatility	Max DD
10%	+137%	0.61	+13.82%	-20.84%
20%	+168%	0.71	+13,46%	-21.88%
30%	+162%	0.69	+13.7%	-22.7%
40%	+169%	0.72	+13.45%	-23.51%
50%	+159%	0.67	+13.84%	-24.18%
60%	+159%	0.69	+12.61%	-25.01%
70%	+149%	0.61	+11.86%	-25.51%
80%	+113%	0.59	+11.76%	-25.49%
90%	+109%	0.59	+11.76%	-25.49%
100%	+109%	0.59	+11.76%	-25.49%

Table 4.5. Benchmark:

	Avg 10 Y Return	Sharpe ratio	Volatility	Max DD
STOXX600	**+109%**	**0.59**	**+11.76%**	**-25.47%**

The Sharpe Ratio is used to help investors understand the return of an investment compared to its risk. Generally, the greater the value of the Sharpe ratio, the more attractive the risk-adjusted return. The sharpe ratio is calculated to:

$$\text{Sharpe Ratio} = \frac{Rp - Rf}{\sigma p} \qquad (4)$$

Where:

- Rp = return of the portfolio
- Rf = risk-free rate
- σp = standard deviation of the portfolio’s excess return

The Sortino ratio is a variation of the Sharpe ratio that differentiates harmful volatility from total overall volatility by using the asset's standard deviation of negative portfolio returns, called downside deviation, instead of the total standard deviation of portfolio returns (Investopedia). The Sortino ratio is a useful way for investors to evaluate an investment's return for a given level of bad risk and is defined to:

$$\text{Sortino Ratio} = \frac{Rp - rf}{\sigma d}$$

Where:

- Rp = actual or expected return of the portfolio
- rf = risk-free rate
- σd = standard deviation of the portfolio’s downside

The main key performance indicators show a much better quality of the patent stocks compared to the benchmark. Especially the correlation of increasing the return with a reduction of the maximum drawdown (Max DD) makes the patent portfolio attractive. The downside risk (Sortino ratio) is as well much better than the index.

From investors' perspective the author recommends the 20% selection, which delivers a high return with a high Sortino ratio and a smaller max DD.

Compared to other fundamental metrics the STOXX 600 Index is as follows:

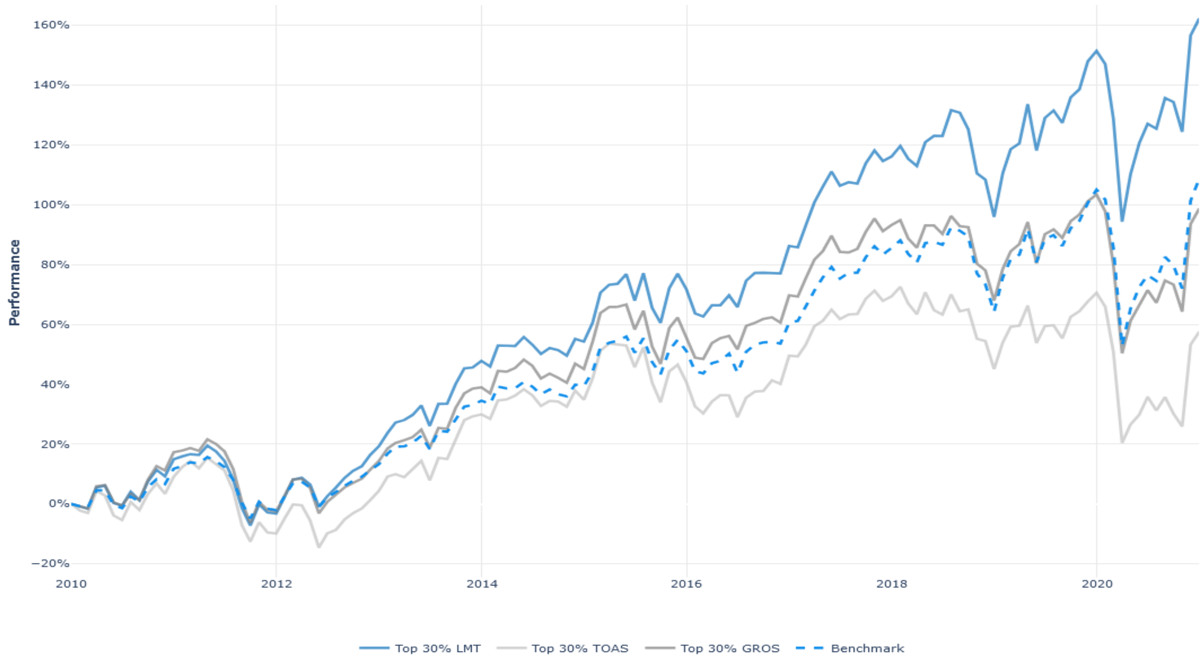


Figure. 4. Performance of Gross profit and total assets compared to patent stocks

Neither the indicator „gross profit" or „Total assets" does deliver an outperformance. Different other indices were backtested, under same conditions like the Stoxx600 which is showed more detailed in this experiment. The results for the other indices are the following:

4.1.2.2 Backtests on S&P500

Backtests on S&P500 show similar results to the STOXX600 index.

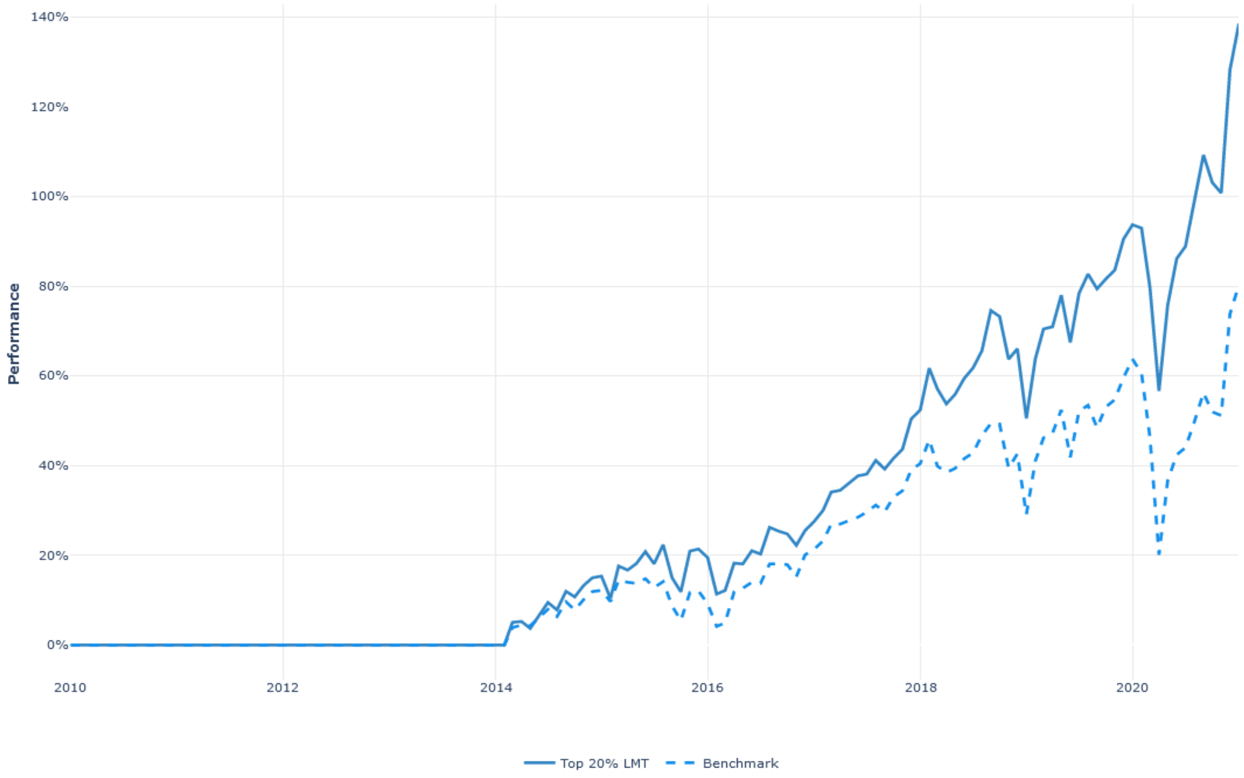


Figure. 5. Performance of the patent stocks for S&P 500

Table 4.6. Key performance indicators of patent stocks on Index S&P500

	Sharpe Ratio	Return	Avg 1 Y Volatility	MAX DD
Patent stocks	**0.76**	**+139%**	**+10.14%**	**-26.63%**
S&P 500	0.54	+80%	+10.96%	-19.12%

4.1.2.3 Backtests on Nikkei 225

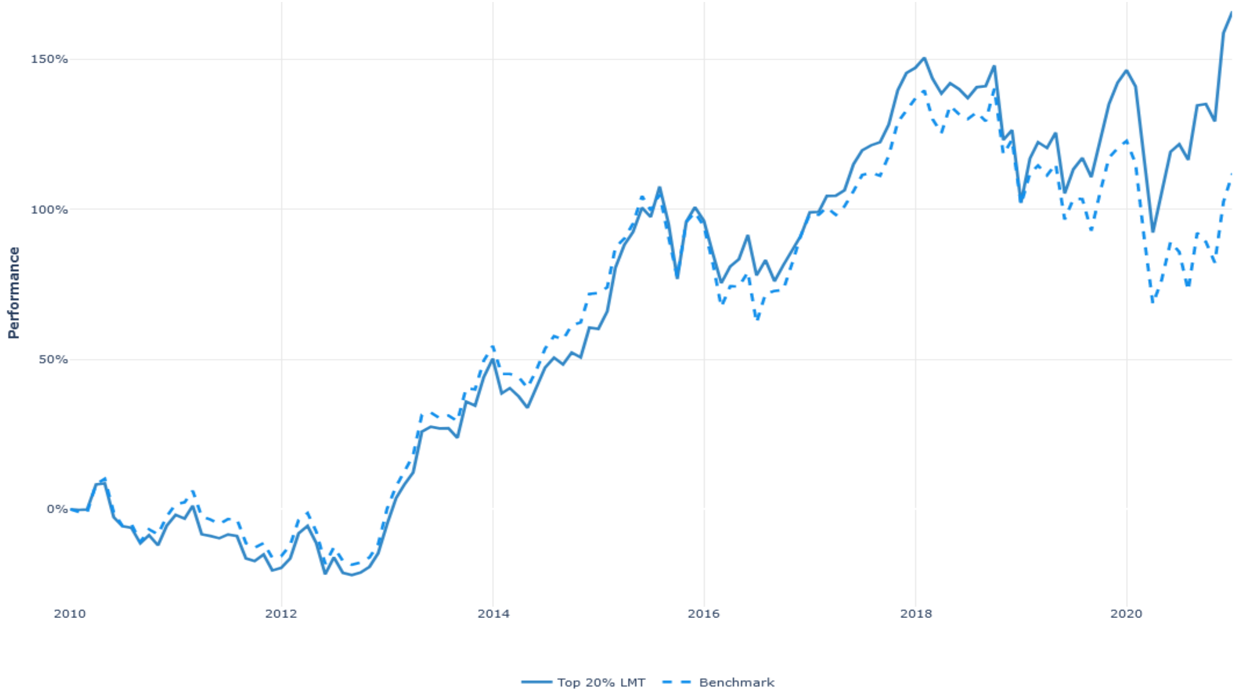


Figure. 6. Performance of the patent stocks on Nickei225 Index

Table 4.7. Key performance indicators of patent stocks on Nikkei225 Index

	Sharpe Ratio	Avg. Return (9Y)	Avg Volatility (9Y)	Max DD
IP Nikkei 225 Index	0.49	+166%	+19.51%	-28.16%
Nikkei 225 Index	0.41	+112%	+21.6%	-29.89%

4.1.2.4 Backtests on CSI300

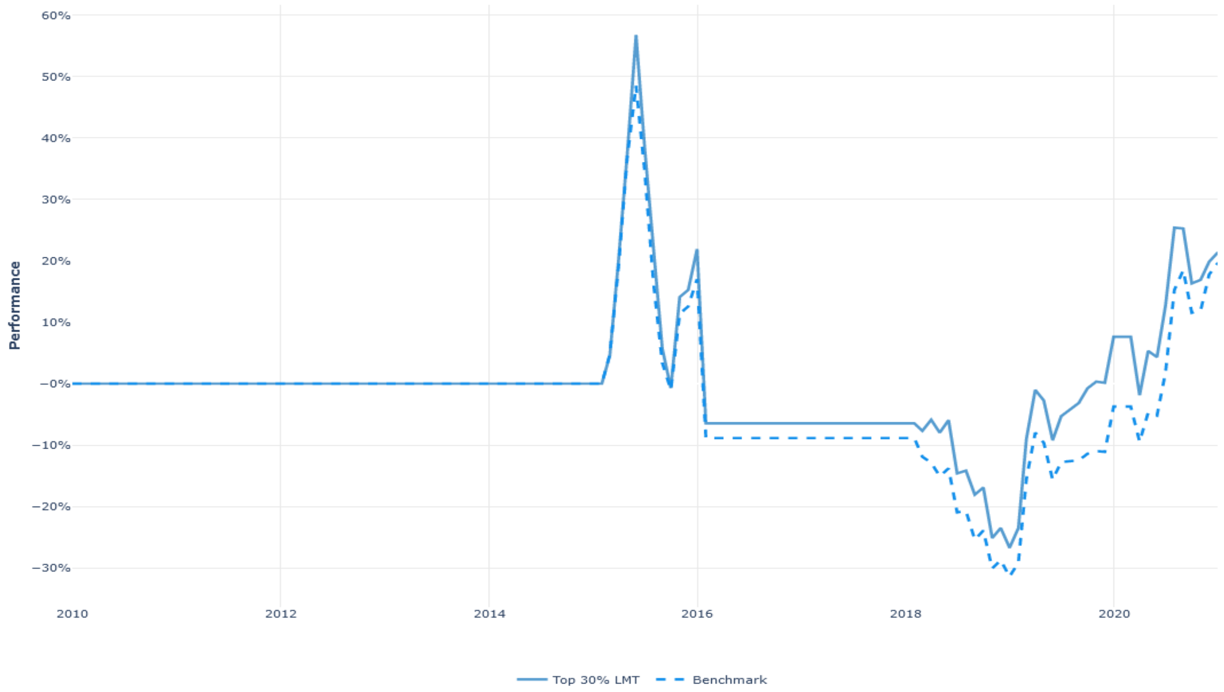


Figure. 7. Performance of the patent stocks on CSI300 Index

Table 4.8. Key performance indicators of patent stocks on the CSI 300 Index

	Sharpe Ratio	Avg. Return (6Y)	Avg. 1 Y Volatility (6Y)	MAX DD
IP Portfolio Index	0.05	21%	+17.66%	-53.84%
CSI 300 Index	0.14	20%	+18.73%	-54.43%

4.1.2.5 Backtests on Nasdaq100

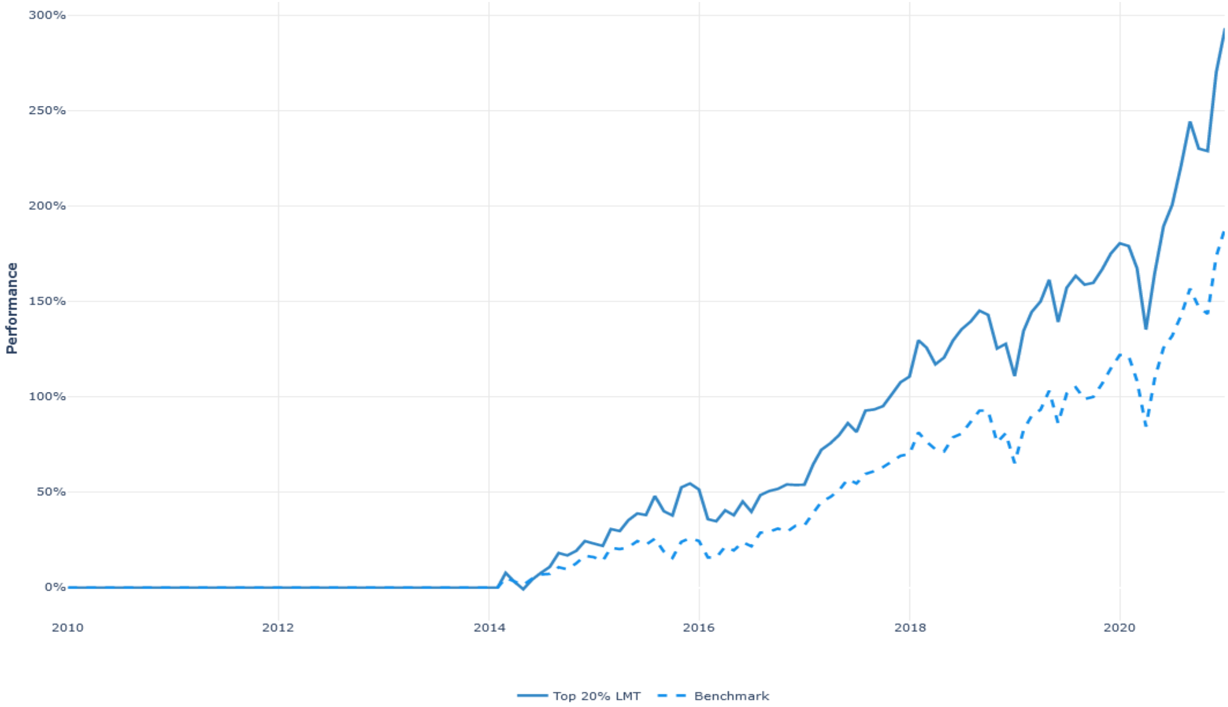


Figure. 8. Performance of the patent stocks on Nasdaq100 Index

Table 4.9. Key performance indicators of patent stocks on Nasdaq100 Index

	Sharpe Ratio	Avg. Return (9Y)	Avg Volatility (9Y)	Max DD
IP Nasdaq 100 Index	0.82	+293%	+16.92%	-16.13%
Nasdaq 100 Index	0.76	+189%	+13.93%	-16.90%

4.1.2.6 Backtests on MSCI World

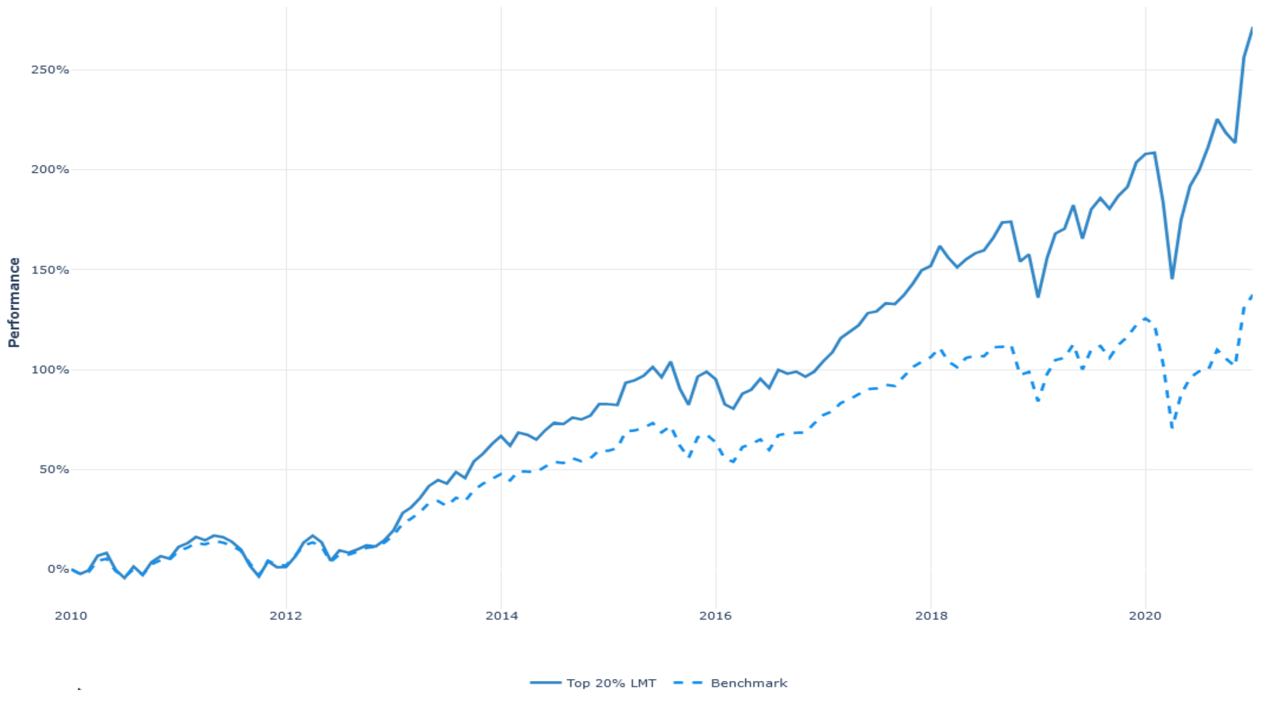


Figure. 9. Performance of the patent stocks on MSCI World

Table 4.10. Key performance indicators of patent stocks on MSCI World Index

	Sharpe Ratio	Avg. Return (9Y)	Avg Volatility (9Y)	Max DD
IP MSCI World Index	0.88	+272%	+14.76%	-20.54%
MSCI World Index	0.72	+138%	+11.2%	-24.39%

4.1.2.7 Backtests on other Indices

Table 4.11. Performance of patent stocks on other indices

	Avg. Return (10Y)
IP MDAX Index	+374%
MDAX Index	+220%
IP CAC40 Index	+22%
CAC40 Index	+2%
IP FTSE250 Index	+232%

FTSE250 Index	+117%
IP Hang Seng Index	+55%
Hang Seng Index	+17%

4.1.2.8 Possible dependencies from other factors

One question which occurs, is if there is bias in the data regarding the size of the company. This analysis was applied for all indices with the results shown in the following table.

Table 4.12. Performance of patent stocks for different company sizes (Market caps). In grey are marked the biggest difference in performance

Index	Performance Patent Stocks			Performance Benchmark Index		
	Small	*Middle*	*Large*	*Small*	*Middle*	*Large*
STOXX600	+365%	+316%	+69%	+202%	+184%	+61%
S&P500	+115%	+94%	+134%	+101%	+85%	+94%
Nickei225	+719%	+153%	+112%	+185%	+109%	+87%
CSI 300	+67%	+24%	+8%	+41%	+3%	-7%
Nasdaq100	+290%	+347%	+312%	+285%	+342%	+214%
MSCI World	+372%	+388%	+232%	+316%	+217%	+131%
MDAX	+2290%	+188%	+137%	+506%	+163%	-23%
CAC40	+22%	+77%	+17%	+1%	+37%	-4%
FTSE250	+588%	+28%	+232%	+337%	+25%	+117%
Hang Seng	+55%	+376%	+42%	+19%	+112%	+3%

From the above analysis there is no size bias obvious. Furthermore, it is very impressing, that for any company size the patent stocks indicator deliver an outperformance and even for some indices which had a negative performance in large caps (CSI, MDAX, CAC40) the patent stock indicator delivers a positive return and not only a lower loss.

One other question is, if there is a certain technology bias in the technology sector. The patent stocks in the different indices were analysed to determine in which sectors the patent portfolio increased most in the past 3 years. The technology sectors were defined by the international patent classifications system (IPC)[1].

Table 4.13. Technology sectors of patent stocks

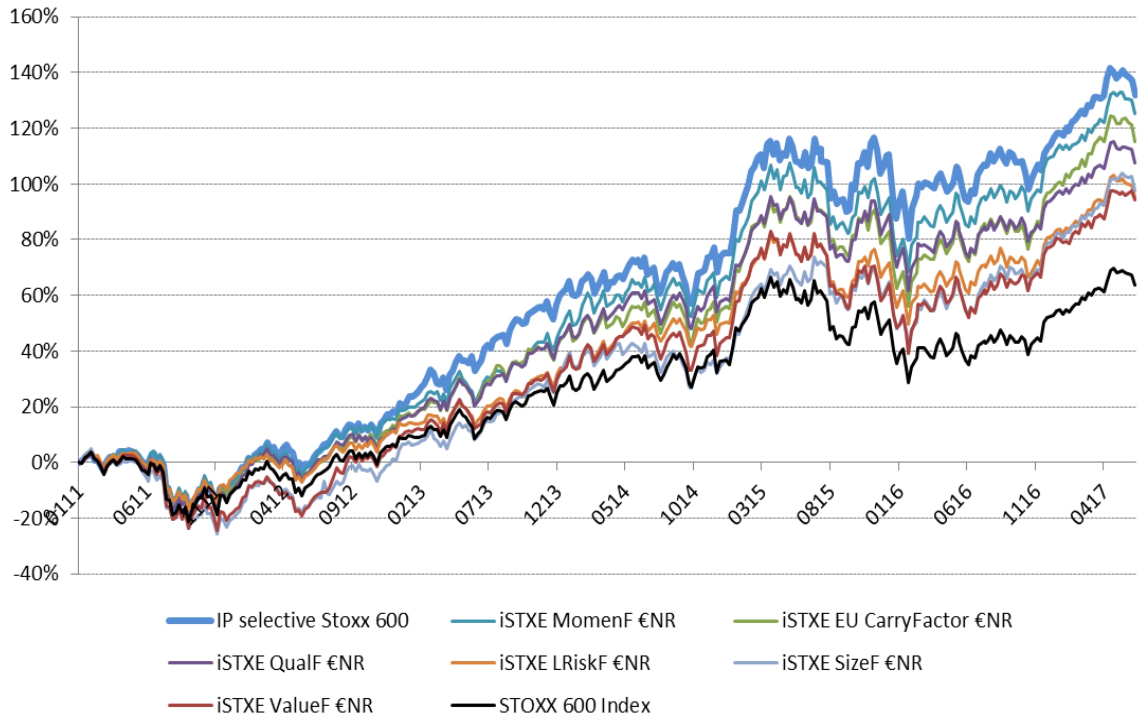
Index	TOP IPC classes in % growth in number of patents			Biggest IPC classes with most alive patents		
STOXX600	B64C	B60W	A47J	A61K	C07D	H04L
S&P500	B64C	B60W		A61K	C07D	H04L
Nickei225	A61B	B60K		H04N	H04L	G03G
CSI 300	A47J	G02F	B60K	F24F	G06F	H04L
Nasdaq100	G06N	A61B	G11B	G06F	H04L	H01L
MSCI World	A61B	B60K	B60W	G06F	H01L	H04L
MDAX	A61K	B60T	B29C	H01L	B64C	B64D
CAC40	B60H	B60W	B62D	A61K	B64C	G06F
FTSE250	E02F	E01F		B22D	G01N	F16L
Hang Seng	G06F	G10L	B60W	E21B	G06F	H04L

4.1.2.9 Correlations and sector Bias

A main question which occurs when a new factor is designed and applied to indices is if the factor has a certain attribute bias? Attribute bias describes the fact that equities that are chosen using one predictive model or technique tend to have similar fundamental characteristics. For the patent factor it is obvious that there could be a bias in technology equities, because those are having the most patents. The current analysis showed that different other sectors like "household" or "food and beverages", which are not classified as "high-tech" are outperforming as well. A look-ahead-bias does not exist because the data were produced at point of time.

[1] International patent classification, IPC , https://www.wipo.int/classifications/ipc/en/

The next important question is if the factor correlates with any other existing factor? Backtests on the factors value, momentum and others are not correlated like the figure 10 shows.



Code	Factor	Description
IP selective Stoxx Europe 600	IP factor	stocks that have high IP Relevance
iSTXE MomenF €NR	Momentum	stocks with exceptional historical price movements
iSTXE EU CarryFactor €NR	Carry	stocks with high carry based on earnings and dividends
iSTXE QualF €NR	Quality	stocks with solid financial background based on debt coverage, earnings and other
iSTXE LRiskF €NR	Low Risk	stocks with risk / vola levels below average
iSTXE SizeF €NR	Size	stocks with low market capitalization / enterprise value
iSTXE ValueF €NR	Value	stocks that are cheap based on cash flow and earnings per share

Figure. 10. Comparison of factors Stoxx 600 versus IP portfolio Index

4.1.2.10 Sector performance

The selected sectors for designing the IP Stoxx index intended to show the market neutrality of the composed index. This means that the index should provide positive returns completely independent of the market conditions. Compared to the STOXX Europe 600 Index the main performance driver are the Sectors Industrial Goods, Healthcare, Food & Beverages, Chemicals, Pers. & HH Goods and Technology.

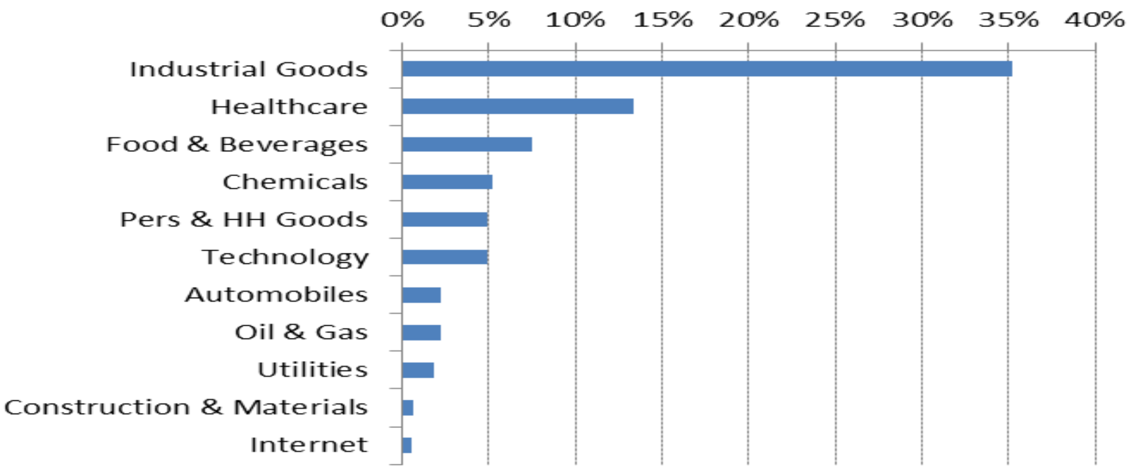


Figure. 11. Sector performance of the Stoxx600 Index

Compared with equal sector weightings to STOXX Europe 600 Index the main performance driver is the Sectors Industrial Goods, Healthcare, Technology, Pers. & HH. Goods, Food & Beverages, Chemicals, Oil & Gas and Telecommunications. In these sectors the influence of the IP Relevance on outperformance is very high.

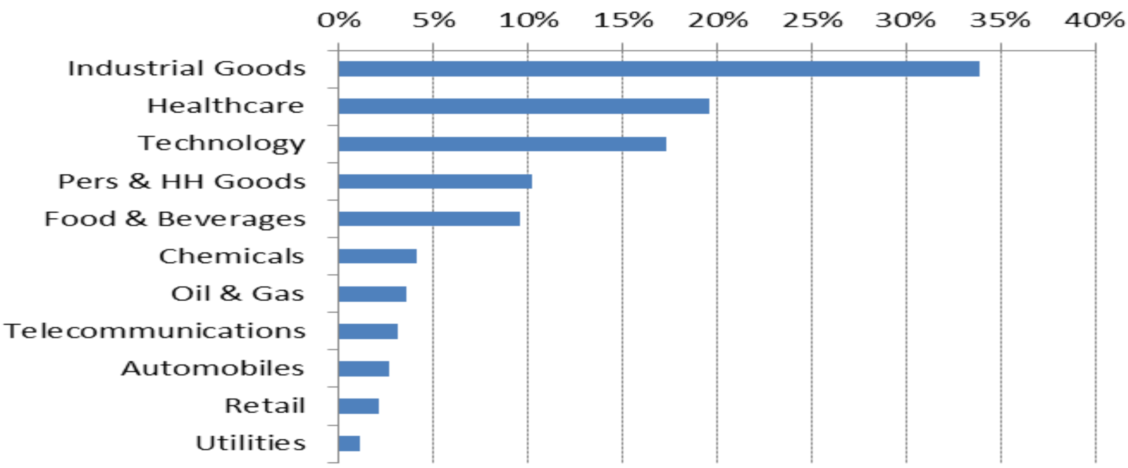


Figure. 12. Sector performance of the IP portfolio STOXX600 vs. Stoxx600 Index

4.1.2.11 Conclusions from this experiment

The current experiment shows that using patent metrics for defining and applying indicators for stock picking is an appropriate method to develop a new factor which can generate alpha in a designed index. The main requirement to use the described metrics determining stocks with high value potential and therefor to improve financial products.

The backtests show correlations for an optimum of the share of patent stocks in an index but no specific technology- or size bias. Further there is no bias on certain regions in the world visible. The basic theory that equities with a high qualitative patent portfolio perform better than those without is proved in the current experiment because all main global indices like Stoxx600, S&P, Nikkei and CSI showed an outperformance in a backtest period of 10 years and even for any company size (based on market cap).

4.2.3 Quantifying Sustainable patents for enhancing ESG factors

Sustainability has become the driving factor in analyzing and evaluating companies. Sustainability became in the past decade one of the most important factor for all stakeholders like customers, employees, business partners and investors. The establishment of the 17 Sustainability Goals from the UN and the Foundation of the UN Global Compact and the UN Principles for Responsible Investments provide an excellent framework and has been proven over years that a focus on sustainability is an important value driver (Kwak and Lee, 2024).

Sustainability ratings focus on historical data provided by the companies and forward-looking trends are mostly not tangible. Terms like Fair, Clean, Sustainable, are often used but are lacking a clear definition and confuse customers and even investors struggle. Thus, approaches which are transparent, forward looking and objective not relying solely on companies self-reporting are highly desired. In the most recent “Report on Benchmarks”, the EU Technical Expert Group on sustainable finance (TEG) proposes, greater disclosure of the methods and benchmarks used to prevent greenwashing (BEAUD, 2006). However, this approach is also criticized, among other things because the proposed benchmarks (the reference values against which a measured sustainability value can be compared and put into relation) would tend to encourage greenwashing due to their lack of variability. The proposals would primarily help ESG data providers (Investopedia:” Environmental, social and governance (ESG) criteria are a set of standards for a company’s operations that socially conscious investors use to screen potential investments. Environmental criteria consider how a company performs as a steward of nature. Social criteria examine how it manages relationships with employees, suppliers, customers, and the communities where it operates. Governance deals with a company’s leadership, executive pay, audits, internal controls, and shareholder rights), but less so investors and thus decision-makers. Accordingly, approaches are desirable that allow a sustainability analysis without relying on any "self-assessment" of the company concerned and where benchmarks and methodology are transparent (Rieu, 2012).

In a sense, patents are the blueprint for the R&D activities of a (technically or scientifically oriented) company. They document the results of successful investments in tomorrow's innovations. These inventions describe in detail the (innovative) approaches to solving problems that one would like to address with new products in the future. Accordingly, the value distribution of a patent portfolio is also the reflection of innovative ability and willingness. Thus, a look at the patent portfolio - and its value distribution - allows a deep insight into R&D activities and a presumed product pipeline.

Alternative data (proprietary datasets) in different areas like geo-location, credit card, social/sentiment or web traffic became very popular over the last years at financial institutions promising additional insights beside business data. ESG data providers are giving an insight into a companies' sustainable activities. Patent data became very popular over the past years because of the currently high quality of the data delivered by the most national patent offices and the possibility to use patent metrics as an indicator to measure the innovation developed by companies (Labère, 2003, Daum, 2003, Hoffman and Barney, 2002, Hofinger, 1999, Parr, 1988, Rings, 2000, Lee, 2002, Pakes, 1984).

A study published by the Canadian company Corporate Knights (Corporateknights) presents a list of 7500 companies with an annual turnover of at least USD 1 billion, from which those that are supposedly the most sustainable are selected. The ranking of the "top sustainable companies" will be compared with the results of the current patent analysis.

4.2.4 Aim of the experiment

- The aim of the experiment is to scientifically prove that patent indicators derived from different metrics have a real market impact especially for the financial sector.
- This experiment shows that patent value indicators build out of bibliometric data are suitable to determine equities which will outperform on a long-term base and can be used as reliable factor to develop smart beta products based on patent related indicators.
- The main theory for using patent indicators is, that the development of the patent portfolio of a company is an early trend indicator and contemporary representing the present status of a company's research- and development output.
- The amount and quality of granted and applied patents are an early stage and trend indicator, because first there is a serious time lag between application and grant of a patent which depends on the patent office, the patent quality itself and the technological sector and is stated to 1-10 years. Secondly patents can be found after several years of their filing in products of the applicant.

- The patenting activity of a company represents as well the current status of a company in terms of revenues and profits, because filing and counter fighting needs available resources in terms of money and human power. Further the development of patents needs a high-class research and development department, which generates innovations, otherwise no patents will be granted. Last but not least, a company which is filing patents with a high quality believes in its own technology and future growth, and is not only optimizing the corporate structure for cost-savings.
- The current experiment endorses the basic theory, that measurement of patent quality is a suitable factor for selecting equities and generating indexes for investment purposes.

4.3 IPC Class Definition

One main task to define sustainable patents is to define the IPC classes in which the patents are applied and granted. The International Patent Classification (IPC) provides for a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain. It consists of 103 classes, 594 subclasses and 61,397 subgroups. For this study 2,786 classes (out of 260,711) have been identified that either address directly sustainable technologies or enable or support them. Patents having a direct impact on a sustainable technology are higher weighted than those that are enablers or supporters.

Example: a patent that is filed in class Y02E10/10 “Reduction of Greenhouse Gas [GHG] emissions, related to energy generation, transmission or distribution - Geothermal energy” directly addresses a sustainable technology. A patent being categorized in Y02W90/00 “Climate change mitigation technologies related to wastewater treatment or waste management - Enabling technologies or technologies with a potential or indirect contribution to greenhouse gas [GHG] emissions mitigation” enables A patent filed in class H02S20/00 “Supporting structures for PV modules” only supports a sustainable technology.

4.3.1 Data Samples

The patent analysis was generated and back tested based on the available data from Orbis IP database and Intracom's proprietary patent database (Intracom, 2023). The data structure is explained in the following table based on a company sample:

Table 4.14. Sample data of an equity

1	ISIN	AN8068571086
2	valuation date	31.12.2018
3	name	SCHLUMBERGER N.V.
4	country	CW
5	LISTED	Listed
6	TotalAssets in 1,000€	61.578.135 €
7	Employees	100.000
8	IPC sector	E21
9	Technology Spec	E21B
10	Number Of Families	8.907
11	Mi	100
12	Ti	85,33
13	Number of ESG relevant families	247
14	Mi,esg	100
15	Ti,esg	94,93
16	Share of ESG related families	2,77 %

The fields 11. and 12. are the calculations of the indicators from chapter 4. The fields 14-16 are the indicators for the subset of the ESG related patents. For a comparison 2-time slides have been chosen: year 2013 and year 2018. Only companies with more than 30 alive patent families were chosen in order to have a statistical relevant amount. The total amount on analysed companies was 4,933 for the year 2013 and 4,859 companies for the year 2018.

4.3.2 Results

The first question in the analysis was to determine whether sustainable patents have a higher quality then the rest of the portfolio.

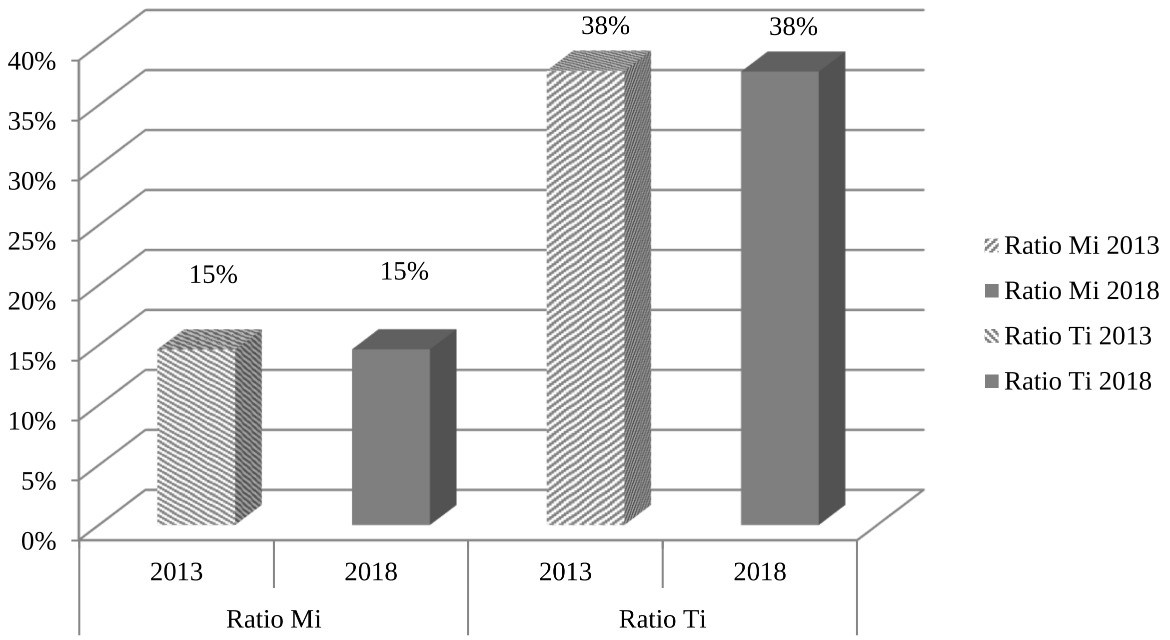


Figure. 13. Ratio Mi and Ti ratio for the years 2013 and 2018

The ratio is always defined to indicator of sustainable patents divided thru the indicator of the complete patent portfolio. The overall analysis shows that only 15% of the sustainable patents have a higher Market impact (Mi) and 38% a higher Technology impact than the rest of the portfolios. Very similar values are for the years 2013 and 2018 therefore the age of the patents can be excluded as factor who has an impact to the indicators. Analysing the companies from the origin of their headquarter delivers the following results:

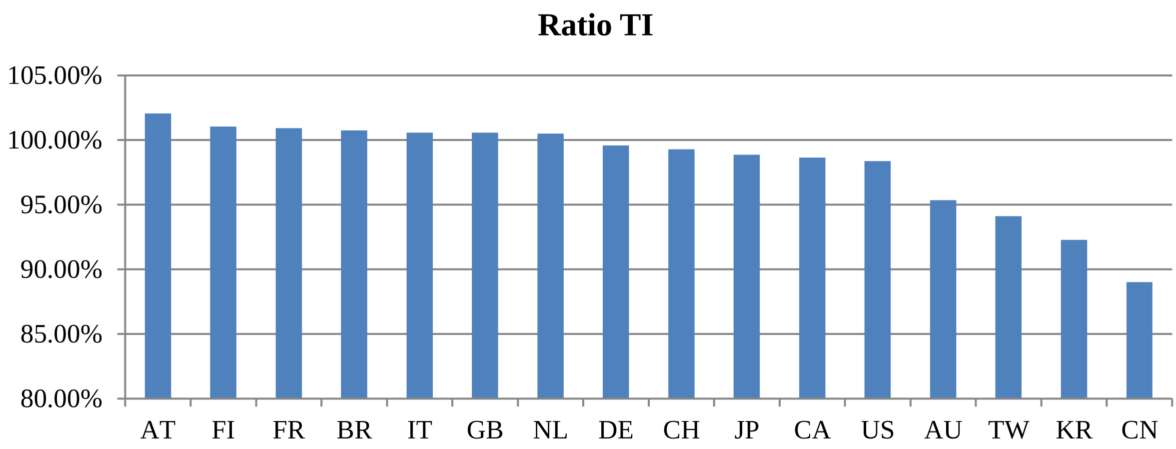


Figure. 14. Ratio Ti for the years 2018 for companies with headquarter [HQ] in country

An interesting result is that companies with HQ in AT, FI, FR, BR, IT, GB and NL have for sustainable patents an even higher technology rating than for the rest of the portfolio.

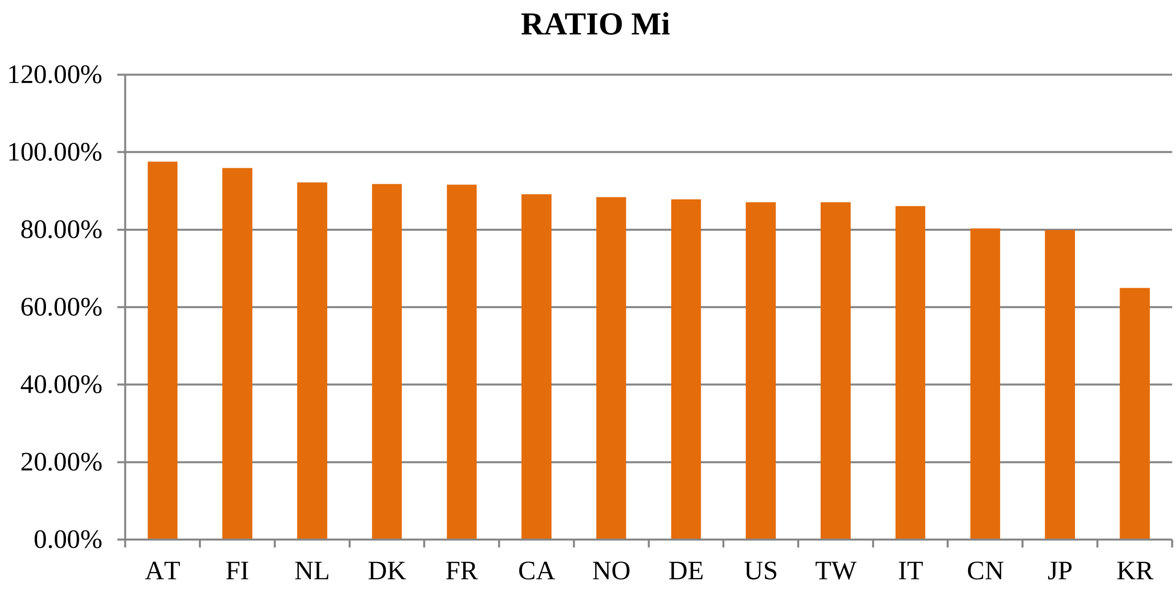


Figure. 15. Ratio Mi for the years 2018 for companies with headquarter in country

The market impact for sustainable patents is smaller than the rest of the portfolio, this can be explained due the sustainable markets which are currently under development. The equities with the highest Mi- and Ti-Ratio have been compared with the ESG rating provider "Reprisk" [34], where AAA is the best and BBB the worst rating:

Table 4.15. Top companies with highest Ti- and Mi ratio - year 2018

No	name	Ratio Mi	Ratio Ti	ESG Rating Reprisk
1	EINHELL GERMANY AG	307,29%	131,75%	AAA
2	MISAWA HOMES CO,, LTD,	256,07%	126,45%	A
3	SANKYO TATEYAMA INC	221,14%	122,40%	A
4	SHIMIZU CORPORATION	206,12%	127,03%	BBB
5	NAKABOHTEC Co PROTECTING	186,28%	124,67%	A
6	RAITO KOGYO CO LTD	176,87%	124,59%	BB
7	EAST JAPAN RAILWAY COMPANY	168,15%	135,72%	BBB

8	NISHIMATSU CONSTRUCTION	152,02%	120,14%	BBB
9	XINJIANG BAYI IRON & STEEL,	144,08%	132,96%	N/A
10	TOPPAN FORMS CO LTD	142,76%	131,84%	BBB
11	RECRUIT HOLDINGS CO,,LTD,	138,69%	127,21%	BB
12	SHINRY TECHNOLOGIES	110,46%	127,31%	BBB
13	D,I, CORPORATION	109,17%	125,41%	A
14	NEXEN TIRE CORP,	104,38%	143,37%	BBB

These companies operate in rather conservative sectors but therefore sustainability has a high impact which is expressed by simultaneously high Mi- and Ti-ratio. Compared to one ESG rating from Reprisk we can identify 8 companies who may have a bad ESG overall rating but they are producing and intending to use sustainable technologies. This additional information could be useful for investors seeking for sustainable companies and to enhance the current ESG rating. The countries with HQ of companies with a high share on sustainable patents (> 30% of the patent portfolio) are as follows:

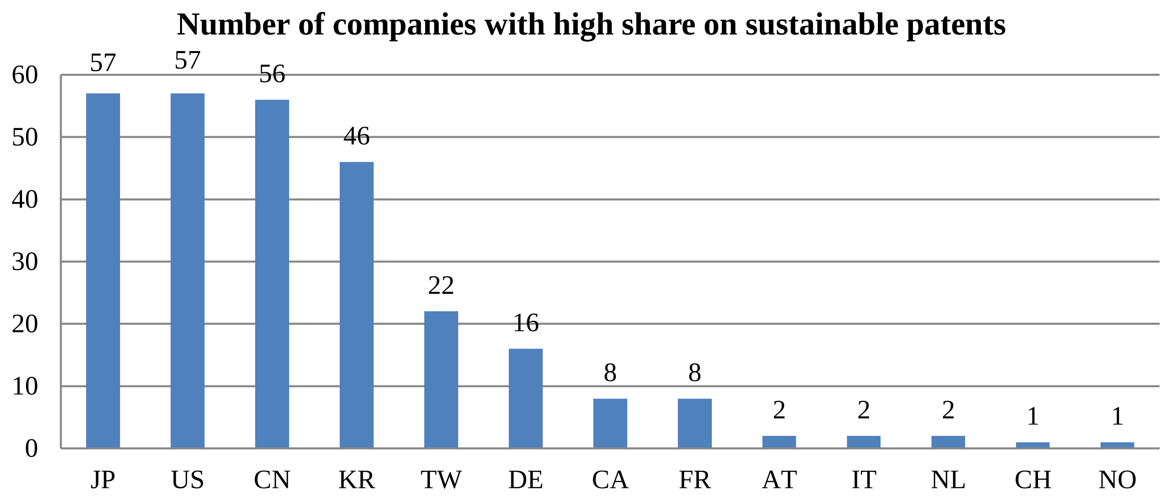


Figure. 16. Number on companies with HQ in countries with high share on sustainable patents (>30% of the portfolio), year 2018

Surprisingly many companies with HQ in Asia are in the leading position. One possible explanation could be the high patenting activity and at the same time the founding of younger companies or subsidiaries from Fortune 500 who are only active in the sustainable sector.

The analysis of the companies' patent portfolios from Corporate Knights study is primarily intended to take a look behind the scenes. Accordingly, the analysis of the patents with regard to sustainable technologies should help to find out which companies have invested particularly in sustainability-R&D (technologies and procedures). Here, a comparison is to be made between a particularly sustainable perception as well as presentation of a company and the sustainability derived from patenting behaviour. The above-mentioned study "The Most Sustainable Companies In 2019" will again be used for this purpose, in order to compare values. In presenting the results, it is again pointed out that the above-mentioned study takes all ESG (Environment, Social and Governance) factors into account. In contrast, the patent analysis presented here focuses mainly on technology aspects of the "E" of ESG.

For the top 50 most sustainable companies according to the above-mentioned study, the respective Mi- and Ti-ratio share of the sustainable patents compared to the total patent portfolio was determined using the same method as in the previous analyses. As a guideline, the respective industry average was calculated from this ratio in order to assess whether the respective company is an above-average (marked with “green arrow”) or below-average (“red arrow”) "sustainable innovator" from the patent portfolio perspective. The Corporate Knights study took several factors into account, but in the table below only the "Carbon Productivity Score", "Clean Revenues" and the "Overall Score" are shown, as these are most comparable with the patent value score.

Table 4.16. Comparison of Top sustainable companies from Corporate Knights study with TI- and Mi.-ratio - year 2018

Rank	Name	country	Overall Score ESG rating	Mi patent ratio	Ti patent ratio	overall rating
1	Chr. Hansen Holding A/S	DK	83,0%	✔	✔	↑
2	Neste Corporation	FI	80,9%	!	!	↓
3	Orsted	DK	80,1%	!	!	↓
4	GlaxoSmithKline plc	GB	79,4%	✔	✔	↑
5	Umicore	BE	79,1%	!	!	↓
6	Shinhan Financial Co.	KR	77,8%	!	!	↓
7	Taiwan Semiconductor	TW	77,7%	!	!	↓
8	Pearson PLC	GB	76,9%	!	!	↓
9	Outotec Oyj	FI	76,5%	!	!	↓
10	Cisco Systems, Inc.	US	76,1%	✔	✔	↑
11	Natura Cosmeticos S.A.	BR	75,6%	!	!	↓
12	Analog Devices, Inc.	US	75,3%	✔	✔	↑
13	Novartis AG	CH	75,2%	!	!	↓
14	Sanofi	FR	75,2%	!	!	↓
15	Ericsson	BR	74,9%	✔	✔	↑
16	Bombardier Inc.	CA	74,8%	✔	✔	↑
17	UPM-Kymmene Oyj	FI	74,4%	!	!	↓
18	bioMerieux SA	FR	72,2%	!	✔	→
19	Royal KPN NV	NL	71,8%	!	!	↓
20	Siemens AG	DE	71,4%	!	!	↓
21	Valeo SA	FR	71,2%	!	!	↓
22	LG Electronics Inc.	KR	71,0%	!	!	↓
23	Ecolab Inc.	US	70,7%	✔	✔	↑
24	Vestas Wind A/S	DK	69,5%	!	!	↓
25	Electrolux AB	SE	69,2%	✔	✔	↑
26	Dassault Systemes SA	FR	69,1%	✔	✔	↑
27	HP Inc.	US	68,3%	✔	✔	↑
28	Kone Oyj	FI	67,2%	✖	✔	→
29	ABB Ltd.	DE	67,0%	✔	✔	↑
30	Eli Lilly and Company	US	66,9%	✔	✔	↑
31	Autodesk, Inc.	US	66,4%	✔	✔	↑
32	Metso Oyj	FI	66,2%	!	!	↓
33	AstraZeneca PLC	GB	65,8%	✔	✔	↑
34	Alphabet Inc.	US	65,6%	✔	✔	↑
35	Danaher Corporation	US	64,9%	✔	✔	↑
36	Halma plc	GB	64,7%	✔	✔	↑
37	Total SA	FR	64,5%	!	!	↓
38	Novo Nordisk A/S	DK	64,4%	!	!	↓
39	Schneider Electric SE	FR	63,6%	!	!	↓
40	Iberdrola SA	ES	62,9%	✔	✔	↑
41	Alstom SA	FR	62,5%	✔	✔	↑
42	Bank of America Corp	US	62,4%	!	✔	→
43	Nokia Oyj	FI	62,2%	!	!	↑
44	Unilever PLC	GB	61,9%	!	!	↑
45	Ingersoll-Rand Plc	IE	61,7%	✔	✔	↑
46	Acciona SA	ES	61,3%	✔	✔	↑
47	Tesla Inc	US	61,3%	!	!	↓
48	Itron, Inc.	US	61,2%	✔	✔	↑
49	Eisai Co., Ltd.	JP	60,0%	✔	✔	↑
50	OSRAM Licht AG	DE	58,6%	!	!	↓

Due the current patent analysis 25 equities from the ranking list can be definitely classified as sustainable, expressed in the patent metrics for sustainable patents (green arrow). For 3 equities it’s not sure (yellow arrow) and for 22 equities there is no impact for sustainable developments of the certain company visible (red arrow). The average thresholds for Mi-Ratio were 83.98% and for the Ti ratio 96.02%.

However, the analysis of the patent portfolios primarily has a sustainability focus and it can reflect only technologies that are inventive; the Corporate Knights study also takes other factors into account, such as gender or salary payment issues. Nevertheless, the patent analyses are very helpful, especially if you look at them in relation to the respective industry average. Nevertheless, these results show that the sustainability analysis of companies should not only rely on "self-assessment" of the companies, their own publications or the presentation from sustainability reports.

4.3.3 Conclusion from this experiment

Patents leave a clear footprint on the activities of a company and it is worth taking a closer look at them, especially since the data has a high availability, is of high quality and highly structured. Patents and metrics for measuring the quality are a well-suited instrument and examined in an over a few hundred studies. Patent metrics are suitable to enrich an ESG profile of a corporation in a sense to make hidden information visible and to make use of high quality, temper proof data. However, patents enlighten only one specific aspect: The R&D activities and their outcome. But his is an important, easy to gather and the missing link within an ESG assessment so far.

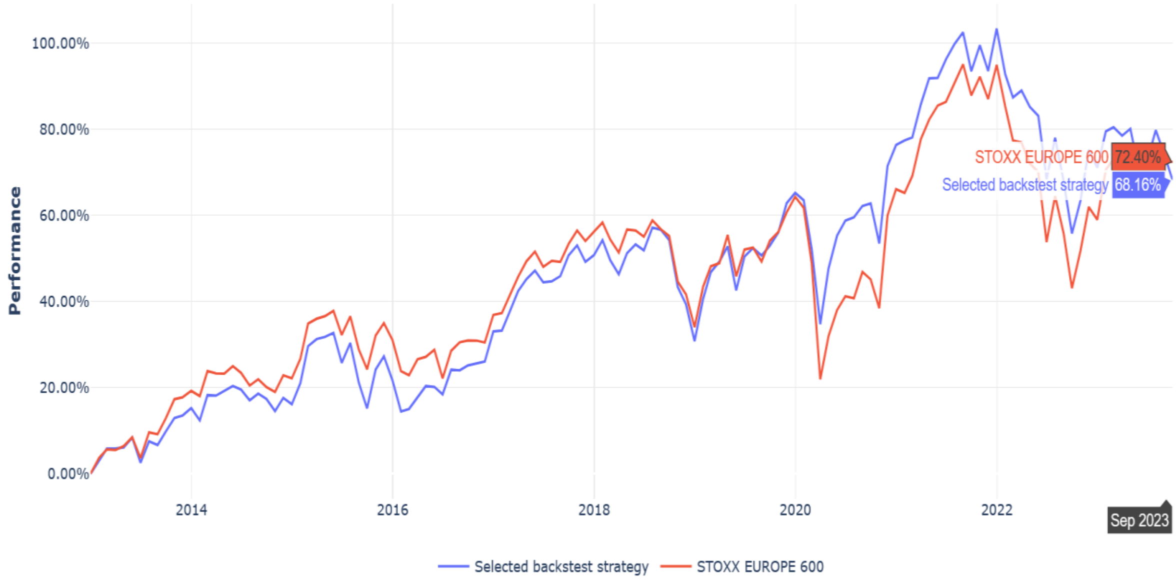
4.4 Applying single qualitative Patent value metrics on global indexes

The different single metrics like Market impact, Technology impact and Assignee impact were solely applied on different indexes in order to determine the contribution of each indicator to the performance of equities. The backtests have been done with quarterly rebalancing and the top 30% of the securities with best KPIs were selected.

4.4.1 Results

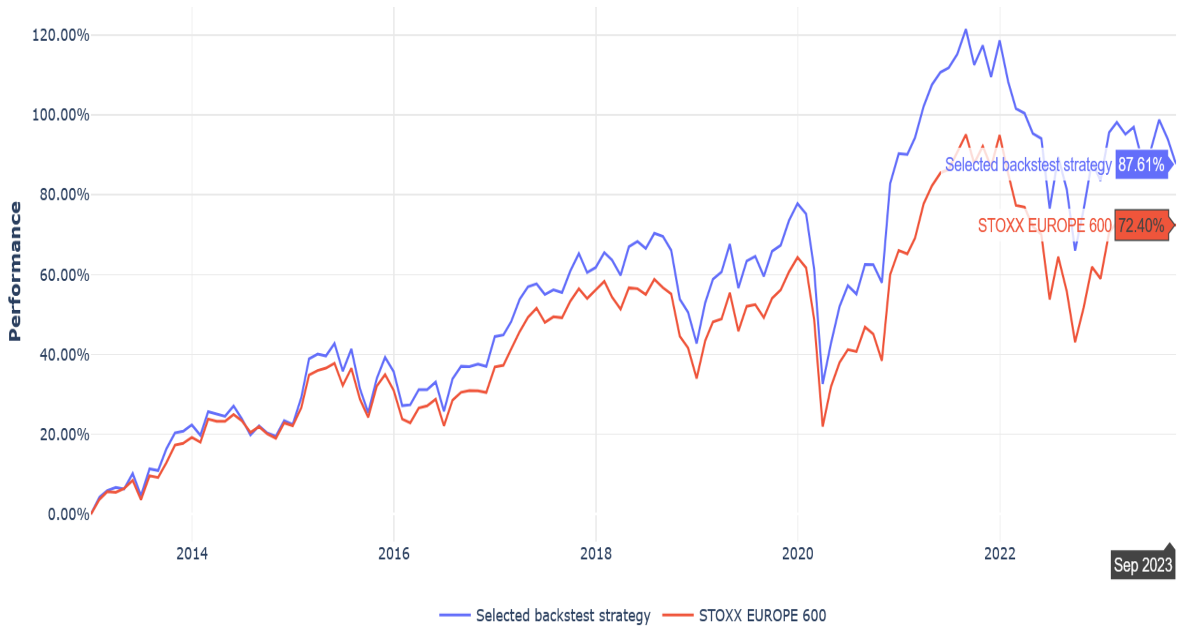
The following results have been generated through the extended backtests: STOXX EUROPE 600

4.4.1.1 Market impact



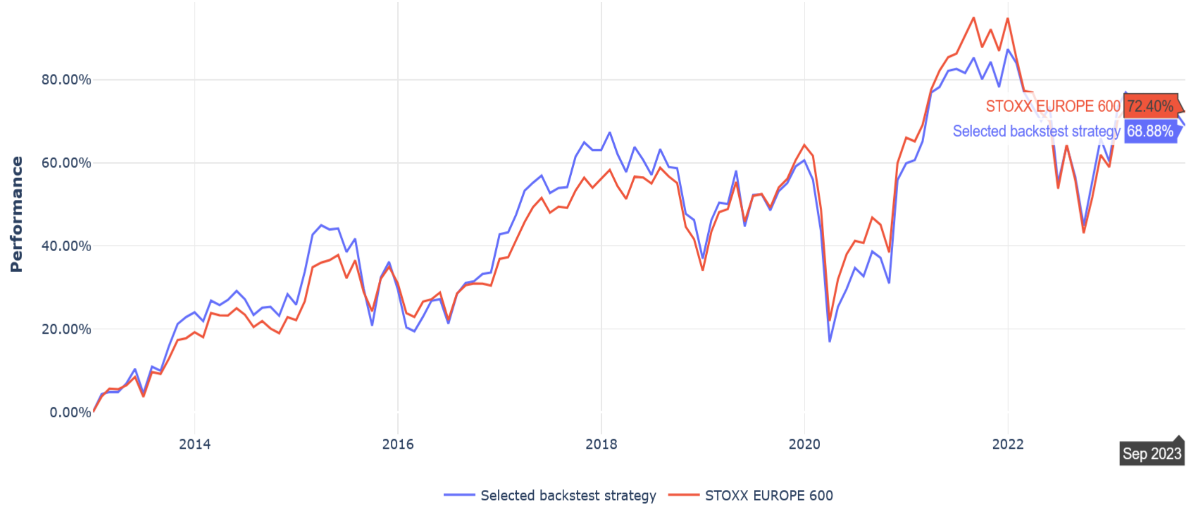
Metric	Selected backtest strategy	STOXX EUROPE 600
Ø performance per year	6.27%	5.59%
Ø turnover in % of portfolio	15.43%	not calculated yet
Ø #IN + #OUT	16.76	not calculated yet
Ø portfolio size	108.56	not calculated yet
Ø Drawdown	-8.27%	-7.11%
Max. Drawdown	-23.40%	-26.65%

4.4.1.2 Technology impact



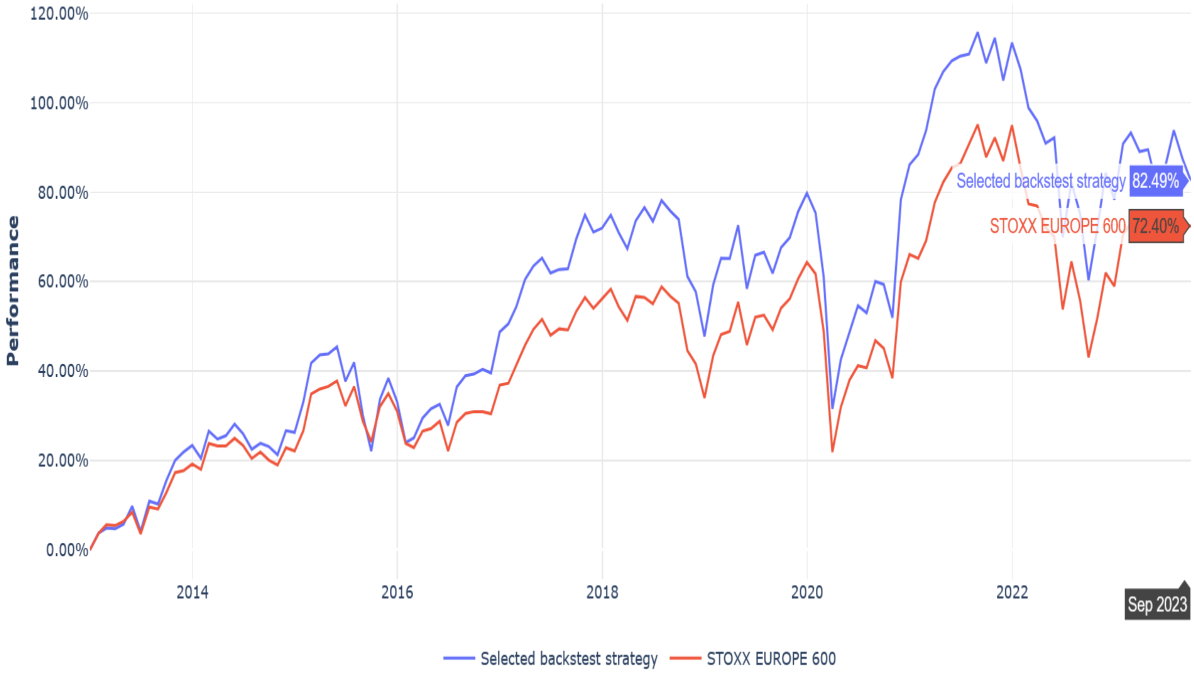
Metric	Selected backtest strategy	STOXX EUROPE 600
Ø performance per year	7.03%	5.59%
Ø turnover in % of portfolio	18.55%	not calculated yet
Ø #IN + #OUT	20.15	not calculated yet
Ø portfolio size	108.83	not calculated yet
Ø Drawdown	-6.45%	-7.11%
Max. Drawdown	-25.42%	-26.65%

4.4.1.3 Assignee impact



Metric	Selected backtest strategy	STOXX EUROPE 600
Ø performance per year	5.64%	5.59%
Ø turnover in % of portfolio	11.29%	not calculated yet
Ø #IN + #OUT	12.29	not calculated yet
Ø portfolio size	108.83	not calculated yet
Ø Drawdown	-7.10%	-7.11%
Max. Drawdown	-30.20%	-26.65%

4.4.1.4 Total quality impact



Metric	Selected backtest strategy	STOXX EUROPE 600
Ø performance per year	6.78%	5.59%
Ø turnover in % of portfolio	17.33%	not calculated yet
Ø #IN + #OUT	18.73	not calculated yet
Ø portfolio size	108.83	not calculated yet
Ø Drawdown	-8.36%	-7.11%
Max. Drawdown	-26.81%	-26.65%

Table 4.17. For other backtested indexes the results are as follows:

		KPI Patentmetrics			
Index	MSCI WORLD	Mi	TI	Ai	TQ
Ø performance per year	7,01	10,13	10,25	9,26%	9,85%
Ø Drawdown	-5,91	-6,57	-5,64	-5,95	-5,90%
Max. Drawdown	-24,75	-21,61	-25,75	-26,05	-25,32%

Index	S&P 500	Mi	TI	Ai	TQ
Ø performance per year	10,14%	11,77%	14,57%	16,88%	16,32%
Ø Drawdown	-5,62%	-12,15%	-10,55%	-6,88%	-9,91%
Max. Drawdown	-27,01%	-43,47%	-39,05%	-30,65%	-35,51%
Index	CSI 300	Mi	TI	Ai	TQ
Ø performance per year	6,10%	5,78%	3,98%	7,85%	6,22%
Ø Drawdown	-31,64%	-12,48%	-19,62%	-31,14%	-20,82%
Max. Drawdown	-46,04%	-43,79%	-51,21%	-45,58%	-45,75%
Index	Nasdaq Composite	Mi	TI	Ai	TQ
Ø performance per year	6,76%	11,77%	14,57%	16,88%	16,32%
Ø Drawdown	-7,45%	-12,15%	-10,55%	-6,88%	-9,91%
Max. Drawdown	-31,25%	-43,47%	-39,05%	-30,65%	-35,51%

Chapter 05: Discussions

Exploring the relationship between patent metrics and stock market performance offers promising avenues for research and potential investment strategy enhancement. However, there are several limitations and challenges that researchers must address to ensure robust and applicable findings.

5.1 Selection Bias

One major limitation is the focus on patent-intensive industries, which can lead to selection bias. This focus may overlook other valuable sectors contributing to market performance through non-patented innovations. Industries like services, real estate, or those with lower patent activity might still play significant roles in market dynamics, but these contributions are often underrepresented in patent-centric analyses.

5.2 Broader Patent Metrics Analysis

Incorporating additional patent metrics presents challenges in terms of complexity and data availability. Expanding metrics such as citation analysis, patent lifespan, and technology convergence requires complex data that may not be readily available for all companies, especially those outside the most patent-heavy industries. Additionally, quantifying intangible factors like technological convergence may not directly correlate with financial performance and can be difficult to quantify accurately. Industry-specific patent analysis faces obstacles like a lack of historical data for emerging industries, making long-term analyses difficult. Moreover, complex interdependencies between sectors complicate efforts to isolate patent metrics' effects on performance, and factors such as regulatory differences and competition intensity can act as potential confounding variables.

5.3 Methodological Constraints

Methodological constraints such as the backtesting period (from 01.01.2010 to 30.04.2021) may not fully capture market cycles, technological changes, or economic events that could affect patent and stock performance. Overfitting risk is another concern; combining numerous metrics increases the risk of overfitting models to historical data, which may not predict future performance accurately. Furthermore, different time horizons between patent data and financial metrics complicate their integration into cohesive models.

5.4 Generalizability

The generalizability of findings is limited due to geographic bias. The indices used in the experiments, such as STOXX600, S&P500, and Nikkei225, mainly represent developed markets. Emerging markets may exhibit different characteristics not captured in this research, making it challenging to apply findings universally.

5.5 Longitudinal Studies and Dynamic Models

Dynamic models must account for complex interactions between patents, market competition, and technological change. Additionally, the changing patent landscape complicates efforts to draw long-term conclusions from historical data. This dynamic nature of patents, where technological advancements can quickly shift the value and relevance of certain patents, poses a significant challenge to creating stable predictive models.

5.6 Investor behavior

Investor behavior adds another layer of complexity, with behavioral biases and irrational behaviors potentially obscuring the true impact of patent metrics on stock performance. Volatility is a common issue, as high patent activity can correlate with increased stock volatility, complicating the integration of risk management strategies. Complex portfolio management becomes necessary when integrating patent metrics into traditional portfolio frameworks, requiring advanced optimization techniques to manage volatility and market risks effectively.

5.7 External Factors

Macroeconomic influences such as economic conditions, regulatory changes, and geopolitical events can significantly impact the performance of patent-centric companies, adding uncertainty to predictions based solely on patent metrics.

5.8 Impact of Technological Disruption

Limited historical data on disruptive technologies poses challenges for analyzing their impact. Predicting disruption with patents involves significant uncertainty and risk, as technological advancements can rapidly alter market dynamics in unpredictable ways.

The exploration of patent metrics and stock market performance presents a significant potential to enhance investment strategies. However, each research direction comes with inherent limitations and challenges. Addressing these issues through improved data collection, advanced analytical techniques, and a nuanced understanding of market dynamics will enhance future research outcomes and provide valuable insights for investors seeking to capitalize on innovation-driven growth. By overcoming these limitations, researchers can better harness patent data to predict and improve stock market performance across diverse industries and regions.

Chapter 06: Conclusions

Patent-based portfolios consistently demonstrate superior performance compared to traditional indices across various markets. They achieve this by exhibiting higher returns, better Sharpe ratios, improved Sortino ratios, and reduced maximum drawdowns. This consistent outperformance is largely due to the inherent value captured through patent value, which effectively identifies high-potential stocks.

Leveraging patent quality metrics gives investors a competitive edge by consistently yielding higher returns and improving risk-adjusted performance across global indices. Investors should be aware of the potential bias toward technology sectors and industries with high patent activity, adjusting their strategies accordingly to capitalize on these strengths. Patent value proves to be a reliable indicator of success across different company sizes, with notable advantages in small-cap stocks that exhibit high innovation potential. Regional performance variations emphasize the necessity for localized strategies and meticulous stock selection based on specific market dynamics. By incorporating qualitative metrics like patent value into investment decision-making processes, investors can achieve superior financial outcomes and enhance investment performance.

Patent metrics serve as a powerful tool for identifying stocks with high potential value, consistently outperforming traditional benchmarks across significant global indices such as the STOXX600, S&P500, Nikkei 225, and CSI300. Over a 10-year period, the patent factor consistently demonstrates superior performance, validating the hypothesis that equities with high-quality patent portfolios outperform those without. Surprisingly, the analysis reveals no significant bias toward technology sectors or specific company sizes, indicating that patent metrics can be effectively applied across diverse industries and company sizes. The absence of regional bias further highlights the universal applicability of the patent factor, ensuring consistent outperformance across various geographical markets—a crucial aspect for global investors seeking a reliable strategy.

Integrating patent metrics into stock selection enhances financial products by offering improved returns and better risk management. This provides a significant competitive advantage through unique value identification. The patent factor serves as a complementary component to existing investment strategies, offering diversification and reducing dependency on traditional factors, which is especially valuable in complex market environments. Investors should incorporate patent metrics into their stock selection processes, especially within sectors with high intellectual property relevance. Focusing on stocks with high-quality patents can lead to significant outperformance, providing an edge in both stable and volatile market conditions. While technology remains a key beneficiary of patent strength, there are also opportunities in undervalued or underappreciated sectors. The universal applicability of patent metrics makes them suitable for global investment strategies, enabling investors to capture value across various markets and regions.

Sustainability has become a critical factor in company evaluations, driven by frameworks like the UN's 17 Sustainability Goals and the UN Global Compact. These frameworks emphasize sustainability as a vital value driver for stakeholders. Traditional ESG ratings often rely on historical data, which may lack transparency and be susceptible to greenwashing. Patents provide a transparent and objective measure of a company's R&D activities and innovation potential, offering insights into future-oriented investments in new technologies and products. By analyzing the quality and volume of patents, particularly those related to sustainable technologies, investors can gain valuable insights into a company's commitment to sustainability and innovation trends.

Across all indices, the application of patent metrics results in significant performance improvements, particularly with Technology Impact (Ti) and Assignee Impact (Ai) metrics in tech-heavy indices like the Nasdaq Composite and S&P 500. The Total Quality metric, which combines Market Impact, Technology Impact, and Assignee Impact, consistently delivers superior performance across all indices, highlighting the importance of considering multiple patent value facets for optimal results. Patent metrics contribute to reduced volatility and lower drawdowns, suggesting that high-quality patents can serve as a buffer against market fluctuations.

Patent metrics serve as a strategic tool for enhancing equity performance in global portfolios, offering investors a unique lens to evaluate innovation potential and market relevance. Given consistent outperformance across indices, patent metrics present a compelling opportunity for developing smart beta products that capitalize on innovation-driven value creation. Investors and fund managers should integrate patent metrics into their investment strategies to capture the innovation-driven growth potential of equities.

Total Quality Impact (TQ), which aggregates a combination of Market Impact [Mi], Technology Impact [Ti], and Assignee Impact [Ai] provides a comprehensive view of a company's patent value, enhancing investment decision-making. This suggests that a holistic approach to evaluating patent portfolios provides the most robust indicator of equity performance.

Potential directions for future researches in the field

The intersection of patent metrics and stock market performance offers a promising area for future research. By exploring various aspects, researchers can uncover new insights, improve predictive models, and develop practical strategies for investors seeking to capitalize on innovation-driven growth.

Future research could focus on developing more granular patent metrics to better understand their correlation with stock performance. This includes exploring a wider range of metrics, such as patent lifespan or technology convergence, to provide deeper insights into the relationship between patents and stock performance. Understanding these factors can help identify influential patents and their impact on a company's competitive advantage.

Combining patent metrics with traditional financial indicators can provide a more comprehensive understanding of a company's value and growth potential. Integrating patent data with financial indicators such as free cash flow, debt levels, or earnings growth could enhance predictive accuracy, leading to more reliable investment strategies.

Leveraging machine learning techniques can uncover hidden patterns and interactions between patent metrics and financial data. AI-driven insights and predictive analytics can forecast stock performance based on historical patent data and emerging technological trends, leading to more informed investment decisions. Understanding how patent portfolio value evolves over time requires developing dynamic models and conducting long-term studies. Developing models that account for changes in patent impact over time, including technological advancements and market dynamics, can provide insights into how patents influence stock performance across different market cycles.

Conducting longer-term studies will help evaluate how patent portfolios evolve and affect stock performance, considering external factors such as competitor market entry, patent expiration, and technological change, offering a more comprehensive view of patent value over time.

Incorporating patent metrics into risk management and portfolio diversification strategies can improve investment resilience and returns. Research should explore how patent metrics can enhance risk management strategies, particularly during market downsides.

Developing real trading models and hedging strategies is a key area for future research. Future studies should focus on creating trading models that combine patent metrics with other quantitative factors, exploring long-short strategies that leverage patents as a component of broader investment strategies. Identifying exit signals, which were not evaluated in the initial studies, is also an important area of exploration. Understanding when to divest from patent-heavy stocks could be as crucial as identifying promising investments.

Exploring the application of patent metrics in other securities like corporate bonds and the development of smart beta products presents a new frontier. Research could focus on creating smart beta products that incorporate patent metrics, offering innovative investment vehicles that capitalize on patent-driven growth. Investigating how patent metrics can be applied to corporate bonds may provide new insights into the bond market, potentially leading to the creation of bond products that reflect a company's innovation capacity.

The ability to predict technological disruption through patent analysis offers exciting possibilities. Researching patent trends as early indicators of technological disruption can provide investors with insights into potential growth opportunities. This involves identifying innovation clusters within patent data that signal upcoming disruptions and their potential market impact. Developing models to predict disruption through patent analysis could offer significant advantages to investors looking to capitalize on emerging technologies and innovations.

The potential for future research in leveraging patent metrics to enhance stock market performance is vast and varied. Each of these areas presents unique challenges and opportunities, promising a rich field of study for academics and practitioners alike. Addressing these research directions through improved data collection, advanced analytical techniques, and understanding of market dynamics will provide valuable insights and practical strategies for investors looking to capitalize on innovation-driven growth.

By overcoming existing limitations, researchers can better harness patent data to predict and improve stock market performance across diverse industries and regions.

7 References

Agostini, L., Caviggioli, F., Filippini, R., & Nosella, A. (2015). Does patenting influence SME sales performance? A quantity and quality analysis of patents in Northern Italy. *European Journal of Innovation Management*, 18, 238-257. https://doi.org/10.1108/EJIM-07-2013-0071.

Aksoy-yurdagul, D. (2015). The Impact of Open Source Software Commercialization on Firm Value. Industry and Innovation, 22, 1 - 17. https://doi.org/10.1080/13662716.2015.1014163.

ALCACER, J., GITTELMAN, M. J. T. R. O. E. & STATISTICS 2006. Patent citations as a measure of knowledge flows: The influence of examiner citations. 88, 774-779.

Amano, T. (2020). The Effect of USPTO's Quality-Improving Initiatives in 2000 on the Claim Scope of Business Method Patents. *Intellectual Property: Patent Law eJournal*. https://doi.org/10.2139/ssrn.3636231.

Aristodemou, L., & Tietze, F. (2018). Citations as a measure of technological impact: A review of forward citation-based measures. *World Patent Information*. https://doi.org/10.1016/J.WPI.2018.05.001.

Atal, V. and Bar, T. (2014), Patent Quality and a Two-Tiered Patent System. J Ind Econ, 62: 503-540. https://doi.org/10.1111/joie.12055

AUGE-DICKHUT, S., MOSER, U., WIDMANN, B., ERNST, W., YOUNG, A. & ERNST, D. A. T. A. 2001. Praxis der Unternehmensbewertung, Olzog.

BARNEY, J. A. J. A. Q. 2002. A study of patent mortality rates: using statistical survival analysis to rate and value patent assets. 30, 317.

Baron, J., & Delcamp, H. (2010). Patent Quality and Value in Discrete and Cumulative Innovation. *ERN: Innovation (Topic)*. https://doi.org/10.2139/ssrn.1709999.

BEAUD, M. 2006. L'Art de la thèse (comment rédiger un mémoire de master, une thèse de doctorat ou tout autre travail universitaire, à l'ère du Net). La Découverte, collection Guides Grands Repères, Paris.

Benson, C., & Magee, C. (2015). Quantitative Determination of Technological Improvement from Patent Data. *PLoS ONE*, 10. https://doi.org/10.1371/journal.pone.0121635.

Bettencourt, L., Lobo, J., & Strumsky, D. (2007). Invention in the city: Increasing returns to patenting as a scaling function of metropolitan size. *Research Policy*, 36, 107-120. https://doi.org/10.1016/J.RESPOL.2006.09.026.

Bollen, L., Vergauwen, P., & Schnieders, S. (2005). Linking intellectual capital and intellectual property to company performance. Management Decision, 43, 1161-1185. https://doi.org/10.1108/00251740510626254.

BURKE, P. F. & REITZIG, M. J. R. P. 2007. Measuring patent assessment quality—Analyzing the degree and kind of (in) consistency in patent offices' decision making. 36, 1404-1430.

Carl Benedikt Frey & Peter Neuhäusler & Knut Blind, 2020. "Patents and corporate credit risk," Industrial and Corporate Change, Oxford University Press and the Associazione ICC, vol. 29(2), pages 289-308.

CARPENTER, M. P., COOPER, M. & NARIN, F. J. R. M. 1980. Linkage between basic research literature and patents. 23, 30-35.

Che, H., & Huang, H. (2010). How to Assess Patent Values in Patent Infringement Lawsuits?. *2010 International Conference on Management and Service Science*, 1-4. https://doi.org/10.1109/ICMSS.2010.5576708.

Chen, Y., & Chang, K. (2010). The relationship between a firm's patent quality and its market value — The case of US pharmaceutical industry. *Technological Forecasting and Social Change*, 77, 20-33. https://doi.org/10.1016/J.TECHFORE.2009.06.003.

Corporateknights, https://www.corporateknights.com

Cotropia, C., & Schwartz, D. (2018). Patents Used in Patent Office Rejections as Indicators of Value. *Sustainable Technology eJournal*. https://doi.org/10.2139/SSRN.3274995.

CRISCUOLO, P. & VERSPAGEN, B. J. R. P. 2008. Does it matter where patent citations come from? Inventor vs. examiner citations in European patents. 37, 1892-1908.

CRISCUOLO, P. J. S. 2006. The'home advantage'effect and patent families. A comparison of OECD triadic patents, the USPTO and the EPO. 66, 23-41.

Cotropia, C., & Schwartz, D. (2018). Patents Used in Patent Office Rejections as Indicators of Value. *Sustainable Technology eJournal*. https://doi.org/10.2139/SSRN.3274995.

Czarnitzki, D., Hussinger, K., & Leten, B. (2011). The Market Value of Blocking Patent Citations. *IRPN: Innovation & Intellectual Property Law & Policy (Topic)*. https://doi.org/10.2139/ssrn.1803315.

Dang, J., & Motohashi, K. (2015). Patent statistics: A good indicator for innovation in China? Patent subsidy program impacts on patent quality. *China Economic Review*, 35, 137-155. https://doi.org/10.1016/J.CHIECO.2015.03.012.

DATA, W. B. O. 2020., https://data.worldbank.org/

DAUM, J. H. 2003. Intangible assets and value creation, John Wiley & Sons.

Dechezleprêtre, A., Ménière, Y. & Mohnen, M. International patent families: from application strategies to statistical indicators. Scientometrics 111, 793–828 (2017). https://doi.org/10.1007/s11192-017-2311-4

DOU, H. J.-M. J. W. P. I. 2004. Benchmarking R&D and companies through patent analysis using free databases and special software: a tool to improve innovative thinking. 26, 297-309.

EPO 2020.

ERNST, L., WITT 2000 Technologie- und Innovationsmanagement.

Fallah, M., Fishman, E., & Reilly, R. (2009). Forward patent citations as predictive measures for diffusion of emerging technologies. *PICMET '09 - 2009 Portland International Conference on Management of Engineering & Technology*, 420-427. https://doi.org/10.1109/PICMET.2009.5262201.

Fischer, T., & Leidinger, J. (2014). Testing patent value indicators on directly observed patent value—An empirical analysis of Ocean Tomo patent auctions. *Research Policy*, 43, 519-529. https://doi.org/10.1016/J.RESPOL.2013.07.013.

Ford, R. (2016). The Patent Spiral. *ERPN: Intellectual Property (Topic)*.

Frietsch, R., Neuhäusler, P., Jung, T., & Looy, B. (2014). Patent indicators for macroeconomic growth—the value of patents estimated by export volume. Technovation, 34, 546-558. https://doi.org/10.1016/J.TECHNOVATION.2014.05.007.

Gambardella, A., Harhoff, D., & Verspagen, B. (2008). The Value of European Patents. *CEPR: Industrial Organization (Topic)*. https://doi.org/10.1057/EMR.2008.10.

GUELLEC, D. & DE LA POTTERIE, B. V. P. J. E. L. 2000. Applications, grants and the value of patent. 69, 109-114.

HAGELIN, T. J. I. 2003. Competitive advantage valuation of intellectual property assets: A new tool for IP managers. 44, 79.

HARHOFF, D., HOISL, K., WEBB, C. J. U. O. M., CEPR , U. O. M. & OECD 2006. European Patent Citations-How to count and how to interpret them.

HARHOFF, D., SCHERER, F. M. & VOPEL, K. J. R. P. 2003. Citations, family size, opposition and the value of patent rights. 32, 1343-1363.

Hirschey, M., & Richardson, V. (2004). Are Scientific Indicators of Patent Quality Useful to Investors?. *ERN: Intellectual Property (Topic)*. https://doi.org/10.1016/J.JEMPFIN.2003.01.001.

HOFFMAN, R. & BARNEY, J. J. T. R. J. 2002. Valuing Patents that are not generating Sales. 84, 73-75.

HOFINGER, S. D. J. H. B. M. 1999. Patente müssen sich rechnen. 21, 101-107.

Hwang, J., Kim, B., & Jeong, E. (2021). Patent Value and Survival of Patents. Journal of Open Innovation: Technology, Market, and Complexity. https://doi.org/10.3390/JOITMC7020119.

INTRACOM 2023. www.intracomgroup.de

IPR 2023. www.ipr-strategies.com

LSEG 2024. https://www.lseg.com

JAFFE, A. B. & DE RASSENFOSSE, G. 2019. Patent citation data in social science research: Overview and best practices, Edward Elgar Publishing.

JANSEN, W. J. E. E. 2009. Examining the relation between patent value and patent claims.

Kabore, F., & Park, W. (2019). Can patent family size and composition signal patent value?. Applied Economics, 51, 6476 - 6496. https://doi.org/10.1080/00036846.2019.1624914.

Kanama, D. (2016). An empirical study on objectives and outcomes of university patents based on the accelerated examination of patent applications in Japan. *International Journal of Technological Learning, Innovation and Development*, 8, 249-264. https://doi.org/10.1504/IJTLID.2016.079612.

Kelly, Bryan, Dimitris Papanikolaou, Amit Seru, and Matt Taddy. 2021. "Measuring Technological Innovation over the Long Run." American Economic Review: Insights, 3 (3): 303-20. DOI: 10.1257/aeri.20190499

Kim, Y., & Oh, J. (2017). Examination workloads, grant decision bias and examination quality of patent office. *Research Policy*, 46, 1005-1019. https://doi.org/10.1016/J.RESPOL.2017.03.007.

Kopczewska, K., & Kopyt, M. (2014). Non-linear corrections in market method of patent valuation. *Business and Economic Horizons*, 10, 177-190. https://doi.org/10.15208/BEH.2014.15.

KWAK, H. & LEE, S. A Study on the Impact of Green Patent Data on ESG Environment Indicators. IEEE/ACIS International Conference on Big Data, Cloud Computing, and Data Science Engineering, 2024. Springer, 183-196.

LABÈRE, N. 2003. Méthodologie de la thèse et du mémoire. Studyrama.

LANJOUW, J. O., PAKES, A. & PUTNAM, J. J. T. J. O. I. E. 1998. How to count patents and value intellectual property: The uses of patent renewal and application data. 46, 405-432.

LANJOUW, J. O. & SCHANKERMAN, M. J. R. J. O. E. 2001. Characteristics of patent litigation: a window on competition. 129-151.

LEE 2002. S. 44.

Lee, C., Kwon, O., Kim, M., & Kwon, D. (2018). Early identification of emerging technologies: A machine learning approach using multiple patent indicators. *Technological Forecasting and Social Change*, 127, 291-303. https://doi.org/10.1016/J.TECHFORE.2017.10.002.

Lin, H., Wang, H., Du, D., Wu, H., Chang, B., & Chen, E. (2018). Patent Quality Valuation with Deep Learning Models. , 474-490. https://doi.org/10.1007/978-3-319-91458-9_29.

Liu, S. (2023). Intellectual Property Protection, R&D Investment and Enterprise Value. The Frontiers of Society, Science and Technology. https://doi.org/10.25236/fsst.2023.050504.

Marco, A., & Miller, R. (2017). Patent Examination Quality and Litigation: Is There a Link?. *International Journal of the Economics of Business*, 26, 65 - 91. https://doi.org/10.1080/13571516.2018.1553286.

Marco, A., Sarnoff, J., & deGrazia, C. (2016). Patent Claims and Patent Scope. *ERPN: Patents (Sub-Topic)*. https://doi.org/10.2139/ssrn.2844964.

Mariani, M., & Romanelli, M. (2007). “Stacking” and “picking” inventions: The patenting behavior of European inventors. *Research Policy*, 36, 1128-1142. https://doi.org/10.1016/J.RESPOL.2007.07.009.

MICHEL, J. & BETTELS, B. J. S. 2001. Patent citation analysis. A closer look at the basic input data from patent search reports. 51, 185-201.

Moser, P., Ohmstedt, J., & Rhode, P. (2016). Patent Citations - An Analysis of Quality Differences and Citing Practices in Hybrid Corn. *LSN: Patent Law/Intellectual Property (Topic)*. https://doi.org/10.2139/ssrn.2754341.

Nair, S., Mathew, M., & Nag, D. (2011). Dynamics between patent latent variables and patent price. *Technovation*, 31, 648-654. https://doi.org/10.1016/J.TECHNOVATION.2011.07.002.

NKOMO, T. 2019. Analysis of Toyota Motor Corporation.

Nikulainen, T., Hermans, R., & Kulvik, M. (2008). Patent Citations Indicating Present Value of the Biotechnology Business. *International Journal of Innovation and Technology Management*, 05, 279-301. https://doi.org/10.1142/S0219877008001436.

Odasso, C., Scellato, G., & Ughetto, E. (2015). Selling Patents at Auction: An Empirical Analysis of Patent Value. *Industrial and Corporate Change*. https://doi.org/10.1093/ICC/DTU015.

Og, J., Pawelec, K., Kim, B., Paprocki, R., & Jeong, E. (2020). Measuring Patent Value Indicators with Patent Renewal Information. , 6, 16. https://doi.org/10.3390/joitmc6010016.

Pachys, F. (2010). Patent Valuation - Impact Factors Through Business Intelligence. *IO: Productivity*. https://doi.org/10.2139/ssrn.1683252.

PAKES, A. 1984. Patents as options: Some estimates of the value of holding European patent stocks. National Bureau of Economic Research.

PARR 1988. S. 36 ff.

Pereira, D., & Leitão, J. (2013). Does the academic spin-off condition play a role in patent valuation?. International Journal of Entrepreneurship and Small Business, 18, 373-399. https://doi.org/10.1504/IJESB.2013.053483.

PITKETHLY, R. J. R. P. I. M. S.-U. O. C. J. I. O. M. S. 1997. The valuation of patents: a review of patent valuation methods with consideration of option based methods and the potential for further research.

Poege, F., Harhoff, D., Gaessler, F., & Baruffaldi, S. (2019). Science quality and the value of inventions. Science Advances, 5. https://doi.org/10.1126/sciadv.aay7323.

PUTNAM, J. D. 1996. The value of international patent rights, Yale University.

REITZIG, M. J. R. P. 2004. Improving patent valuations for management purposes—validating new indicators by analyzing application rationales. 33, 939-957.

RIEU, J.-F. 2012. Rédigez efficacement vos rapports et thèses, Éd. ENI.

RINGS, R. 2000. Patentbewertung: Methoden und Faktoren zur Wertermittlung technischer Schutzrechte.

SAMPAT, B. N. J. G. I. O. T., WORKING PAPER 2004. Examining patent examination: an analysis of examiner and applicant generated prior art.

Schettino, F., Sterlacchini, A., & Venturini, F. (2013). Inventive Productivity and Patent Quality: Evidence from Italian Inventors. . https://doi.org/10.1016/J.JPOLMOD.2013.02.008.

SHEPHERD, E. J. J. O. T. A. S. F. I. S. & TECHNOLOGY 2010. Electronic Records in the Manuscript Repository. 61, 1512-1513.

Shu, T., Tian, X., & Zhan, X. (2020). Patent Quality and Firm Value: Evidence from Patent Examiners Busyness. . https://doi.org/10.2139/SSRN.3137894.

Singh, S. (2018). Patenting Matters, Not Patents: Firm Market Value in Indian Manufacturing. *Margin: The Journal of Applied Economic Research*, 12, 67 - 87. https://doi.org/10.1177/0973801017738423.

SMITH, G. V. & PARR, R. L. 2004. Intellectual property: Licensing and joint venture profit strategies, John Wiley & Sons.

Squicciarini, M., Dernis, H., & Criscuolo, C. (2013). Measuring Patent Quality. . https://doi.org/10.1787/5K4522WKW1R8-EN.

Suh, J. (2015). Exploring the effect of structural patent indicators in forward patent citation networks on patent price from firm market value. Technology Analysis & Strategic Management, 27, 485 - 502. https://doi.org/10.1080/09537325.2015.1011613.

Suzuki, J. (2011). Structural modeling of the value of patent. *Research Policy*, 40, 986-1000. https://doi.org/10.1016/J.RESPOL.2011.05.006.

Svensson, R. (2020). Patent value indicators and technological innovation. Empirical Economics, 62, 1715 - 1742. https://doi.org/10.1007/s00181-021-02082-8.

Tahmooresnejad, L., & Beaudry, C. (2018). Capturing the economic value of triadic patents. Scientometrics, 118, 127 - 157. https://doi.org/10.1007/s11192-018-2959-4.

Thoma, G. (2014). Composite value index of patent indicators: Factor analysis combining bibliographic and survey datasets. *World Patent Information*, 38, 19-26. https://doi.org/10.1016/J.WPI.2014.05.005.

TRAJTENBERG, M. 1990a. Economic analysis of product innovation: The case of CT scanners, Harvard University Press.

TRAJTENBERG, M. J. T. R. J. O. E. 1990b. A penny for your quotes: patent citations and the value of innovations. 172-187.

Trappey, Amy & Trappey, Charles & Govindarajan, Usharani Hareesh & Sun, John. (2019). Patent Value Analysis Using Deep Learning Models—The Case of IoT Technology

Mining for the Manufacturing Industry. IEEE Transactions on Engineering Management. PP. 1-13. 10.1109/TEM.2019.2957842.

USPTO 2009. Manual of Patent Examining Procedure (MPEP).

VAN DIJK, B. 2019. Orbis: Powering the business of certainty.

VAN POTTELSBERGHE, B. & VAN ZEEBROECK, N. 2008. Filing strategies and patent value. EcoMod.

VAN ZEEBROECK, N. J. C. E. B., UNIVERSITE LIBRE DE BRUXELLES. WORKING PAPER 2009. Filing strategies and the increasing duration of patent applications. 9.

Verhoeven, D., Bakker, J., & Veugelers, R. (2015). Measuring Technological Novelty with Patent-Based Indicators. *Innovation Measurement & Indicators eJournal*. https://doi.org/10.2139/ssrn.2382485.

VERSPAGEN, B. & CRISCUOLO, P. 2005. Does it matter where patent citations come from?: inventor versus examiner citations in European patents.

Vitt, C., & Xiong, H. (2015). The Impact of Patent Activities on Stock Dynamics in the High-Tech Sector. 2015 IEEE International Conference on Data Mining, 399-408. https://doi.org/10.1109/ICDM.2015.95.

Xiao-bing, X. (2007). Patent value indicators and their structure. Studies in Science of Science.

ZAGOS, A. & BRAD, S. J. Q.-A. T. S. 2012. Improvements in patent portfolio valuation with bibliometric indicators. 13, 451-454.