Faculty of Business and Economics – Antwerp Management School

Ph.D. Dissertation

AN EMPIRICAL INVESTIGATION INTO THE RELATIONSHIP BETWEEN THE QUALITY AND VALUE OF PATENTS

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27 Mar 2023

Acknowledgments

"The biggest adventure you can ever take is to live the life of your dreams."

Oprah Winfrey

Though my Ph.D. journey began officially on 12th Oct 2019 (what nostalgia!), there were early indications of things to come. In 2003, at the Institute of Chemical Technology (my alma mater), Prof. Padma Devrajan *almost* convinced me that I should enroll in a Ph.D. I did not take her advice seriously as my dream then was to live a corporate lifestyle; I must confess, I have fully lived this dream (at least, so far). I was in 2013 labeled as a Ph.D. "material" by one of my mentors at my current employer Ashland Inc. (erstwhile International Specialty Products) Dr. John Doney. My moment of reckoning came in 2018 when I was mid-way into the Post Graduate Program in Business Analytics and Business Intelligence at the Great Lakes Institute of Management (India) when I realized (maybe, a calling) that I had to invest further in my education; obviously, what remained to be conquered was a terminal degree. And a Ph.D. in management it had to be because I wanted to leverage my professional experience and conduct research in the field of patents. Thus, Antwerp Management School (AMS) happened, one of the finest higher education institutions in Europe, home to an enviable and unparalleled executive Ph.D. program in management.

From 2019 until today in 2023, every moment in my Ph.D. journey has been magical. Ask my greatest blessing for a Ph.D. candidate — my promoter, Prof. Bart Cambre; he will not bat an eyelid and tell you that I am *very* ambitious. Yet, he has been so supportive and encouraging of my pursuit and seriously kept up with my pace. I think I pushed him to the limits with (almost) everyday WhatsApp comments, weekly update emails, biweekly journal rejection emails, and monthly recommendation letter requests. Honestly, I think an association like this happens only once in a generation (you bet).

Thank you, Lord, for giving me Prof. Steffi Weil, the Ph.D. program director and my greatest supporter, and Prof. Markus Kittler from MCI Innsbruck. I learned the first and perhaps the biggest research lesson of *conceptual* reasoning from Markus. I used the lesson to upend the rejection of my second paper by a *Research Policy* editor when I rewrote the manuscript with a more conceptual focus. I also owe so much to the modest person I have ever met — Prof. Henry Delcamp; his coming on board as a subject matter expert for my Ph.D. from outside AMS was so crucial to get my research started.

My better half Sureka has been the biggest anchor in my toughest endeavors; my Ph.D. is not an exception. The poor one is the only testimony to my struggle underneath my (apparently) calm exterior. A cute duck that seems floating on tranquil waters on a placid lake is pedaling with full might under the surface of the water, unknown to an outsider. My friends Akshay Kadam, Pritesh Raikar, Moreshwar Raut, Raghu Dontula, Boidehi Kalita, and Sharmila Sengupta are special additions to my life for which I am grateful. I have made an amazing bunch of international pals from the executive Ph.D. cohort of 2019; I will cherish this association for a long time. Finally, I must mention two people who have had possibly the most significant influence on my career at Ashland, Dr. David Hood and Dr. Osama Musa. Their constant encouragement, appreciation, and support for over a decade have enabled me to carve a niche in my role at Ashland; this unique position acted as the fuel for my Ph.D.

Living the Ph.D. dream has been a life-defining experience for me. I sign off with a profound note from the Hindu scriptures — *that (sā) is knowledge (vidyā) which (yā) liberates (vimuktaye).*

Doctoral Jury

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Summary

Purpose: Patents are intangible intellectual property rights that enable innovators to obtain a competitive and sustainable business advantage. The objectives of this thesis are to (a) understand what are the dimensions of patent quality, (b) find out how is patent quality related to patent value, and (c) investigate the effect of the relationship between certain unexplored dimensions of patent quality and patent value.

Approach, Methodology, Design, and Analysis: This research involves two approaches across three component studies. The first approach of theoretical elaboration encompasses conceptualizing and executing empirical research using pre-existing conceptual ideas or a preliminary model as a basis for developing new theoretical insights. Consistent with this approach, I conduct a systematic literature review (SLR) in my first study as an effective method to consolidate the findings from a burgeoning body of empirical literature; the core concepts of *patent value* and *patent quality* are studied extensively across disciplines and are largely characterized by idiosyncratic considerations and definitions for these, particularly for the latter.

In my second approach for the second and third studies, consistent with the dominant research philosophy of positivism in extant literature in the field of innovation economics, I use deductive logic. Using the quantitative methodology, I build upon the findings from my first study and investigate the effect of certain unexplored aspects of patent quality on patent value. The design for both the second and third studies involves the collection of archival (panel) data on patents published by the United States Patents and Trademark Office (USPTO). The principal source of data is the Patent Examination Research Dataset (PatEx) from the USPTO, which consists of multiple component datasets having information on a variety of patent characteristics for more

than nine million patents (patent applications and granted patents published through 2019). I also use several supplementary data sources from the USPTO — the Patent Litigation Dataset, the Patent Claims Research Dataset, the Patent Assignment Dataset, and the Office Action Research Dataset for Patents. Additionally, I use PatentsView, which is a data visualization and bulk data download platform supported by the USPTO, and a recently published dataset in academia having information on the market (dollar) value of patents assigned to publicly-listed firms in the U.S.

For the SLR, using content analysis, I synthesize the information from the corpus of textual data from 340 relevant papers to delineate the different types of indicators and dimensions of patent quality and value. For my two quantitative studies, I choose the component datasets from PatEx depending on the nature of my research question(s). I use data from sample sizes ranging from about half a million to about 2.3 million granted patents to construct my two research variables – *patent scope* and *readability of patent disclosures* – using text mining techniques in R programming language. I obtain the information on my response and control variables from different PatEx datasets and merge them using a common identifier. I employ different econometric analysis techniques such as OLS, negative binomial, and logistic regressions to obtain the estimates of the coefficients of the independent variables in my models.

Findings: In my first study, I integrate the findings from the relevant papers from the SLR and advance an elaborated conceptual model which relates the different dimensions of patent quality and patent value. Particularly, I delineate four dimensions of regulatory patent quality – *subject matter*, *utility*, *non-obviousness or inventive step*, and *sufficiency of disclosure*. In my second study, I explicate a *valid*, *robust*, and *complementary* measure of *patent scope* (a subdimension of the *utility* dimension of patent quality). I find that innovators use this subdimension of patent scope strategically to *broaden* the scope of the patent at grant whilst the patent examiners typically curtail the scope of the granted patent along the other known subdimensions of patent scope. I also find strong support for my hypothesized positive relationship between patent scope and several measures of patent value. In my third study, I find strong support for my hypothesized positive relationship between the disclosure quality of patents (*sufficiency of disclosure* dimension of patent quality) and patent value in the markets for technology and finance.

Originality/value: The study makes a theoretical contribution by (a) advancing the emergent ex-ante theory of patent value by elaborating a conceptual model that relates the different dimensions of patent quality and patent value and (b) testing certain relationships that underpin the ex-ante theory in an empirical setting. The study contributes to practice by informing on the substantivity of the effect of certain dimensions of patent quality on patent value. The study contributes to policy by suggesting that (a) innovators can be incentivized to file patent applications of high quality which would improve the efficiency and reputation of the patent office which is criticized for granting too many patents of poor quality, and (b) there are systemic problems in the U.S. which legally authorizes patents of poor quality (or overly broad scope) in the first place even if these patents meet the standards of patentability laid down by the patent office. Finally, the study makes empirical contributions by (a) differentiating, defining, and relating the important concepts of patent quality and patent value in a theoretical framework, which seeks to overcome the problem of confounding these concepts in the extant empirical literature, and (b) identifying and validating a hitherto unknown but important dimension of patent scope which is based on the meaning of certain specific scope-related terms in the patent claims.

Nederlandstalige Samenvatting

Doel: Octrooien zijn immateriële intellectuele eigendomsrechten die innovators in staat stellen, om een concurrerend en duurzaam bedrijfsvoordeel te behalen. De doelstellingen van dit proefschrift zijn om (a) te begrijpen wat de dimensies van octrooikwaliteit zijn, (b) uit te zoeken hoe octrooikwaliteit gerelateerd is aan octrooiwaarde, en (c) het effect te onderzoeken van de relatie tussen bepaalde onontgonnen dimensies van octrooikwaliteit en octrooiwaarde.

Aanpak, methodologie, design en analyse: Dit onderzoek omvat twee benaderingen in drie componentenstudies. De eerste benadering is een theoretische uitwerking en omvat het conceptualiseren en uitvoeren van empirisch onderzoek met behulp van reeds bestaande conceptuele ideeën of een voorlopig model als basis voor het ontwikkelen van nieuwe theoretische inzichten. In overeenstemming met deze benadering, voer ik in mijn eerste studie een systematisch literatuuronderzoek (SLR) uit, als een effectieve methode, om de bevindingen uit een ontluikende hoeveelheid empirische literatuur te consolideren; de concepten van *octrooiwaarde* en *octrooikwaliteit*, worden uitgebreid bestudeerd over disciplines heen en worden grotendeels gekenmerkt door idiosyncratische overwegingen en definities, met name voor de laatstgenoemde.

In mijn tweede benadering voor de tweede en derde studie, consistent met de dominante onderzoeksfilosofie van positivisme in bestaande literatuur op het gebied van innovatie-economie, gebruik ik deductieve logica. Met behulp van de kwantitatieve methodologie bouw ik voort op de bevindingen uit mijn eerste studie en onderzoek ik het effect van bepaalde onontgonnen aspecten van octrooikwaliteit op de octrooiwaarde. Het ontwerp voor zowel de tweede als de derde studie omvat het verzamelen van archiefgegevens (panel) over octrooien gepubliceerd door het United States Patents and Trademark Office (USPTO). De belangrijkste bron van gegevens is de Patent

Examination Research Dataset (PatEx) van de USPTO, die bestaat uit datasets met meerdere componenten met informatie over een verscheidenheid aan octrooikenmerken voor meer dan negen miljoen patenten (octrooi -aanvragen en verleende octrooien gepubliceerd tot en met 2019). Ook gebruik ik verschillende aanvullende gegevensbronnen van de USPTO - de Patent Litigation Dataset, de Patent Claims Research Dataset, de Patent Assignment Dataset en de Office Action Research Dataset for Patents. Daarnaast gebruik ik PatentsView, een platform voor gegevens-visualisatie en bulkgegevensdownload dat wordt ondersteund door de USPTO, en een onlangs gepubliceerde dataset in de academische wereld, met informatie over de marktwaarde (dollar) van octrooien die zijn toegewezen aan beursgenoteerde bedrijven in de U.S.

Voor de SLR, met behulp van inhoudsanalyse, synthetiseer ik de informatie uit het corpus van tekstuele gegevens, uit 340 relevante artikelen, om de verschillende soorten indicatoren en dimensies van octrooikwaliteit en -waarde af te bakenen. Voor mijn twee kwantitatieve studies kies ik de component datasets van PatEx afhankelijk van de aard van mijn onderzoeksvraag(en). Ik gebruik gegevens van steekproefgroottes variërend van ongeveer een half miljoen tot ongeveer 2,3 miljoen toegekende patenten om mijn twee onderzoeks-variabelen - *patentbereik* en *leesbaarheid van octrooiverschaffing* - te construeren met behulp van text mining-technieken in R-programmeertaal. Ik verkrijg de informatie over mijn respons- en controlevariabelen uit verschillende PatEx-datasets en voeg deze samen met behulp van een gemeenschappelijke identificatie. Ik gebruik verschillende econometrische analysetechnieken zoals OLS, negatieve binomiale en logistische regressies om de schattingen van de coëfficiënten van de onafhankelijke variabelen in mijn modellen te verkrijgen.

Bevindingen: In mijn eerste studie integreer ik de bevindingen uit de relevante artikelen van de SLR en ontwikkel ik een uitgewerkt conceptueel model dat de verschillende dimensies van octrooikwaliteit en octrooiwaarde relateert. In het bijzonder baken ik vier dimensies af van de kwaliteit van regelgevende octrooien - *onderwerp*, *nut*, *niet-vanzelfsprekendheid of inventieve stap*, en *toereikendheid van openbaarmaking*. In mijn tweede studie, verklaar ik een *geldige*, *robuuste* en *complementaire* maat voor *de reikwijdte van octrooien* (een subdimensie van de gebruiksdimensie van octrooikwaliteit). Ik vind dat innovators deze subdimensie van het octrooibereik strategisch gebruiken om de reikwijdte van het octrooi bij verlening te *verbreden*, terwijl de octrooionderzoekers doorgaans de reikwijdte van het verleende octrooi beperken langs de andere bekende subdimensies van de octrooiomvang. Ik vind ook sterke steun voor mijn veronderstelde positieve relatie, tussen octrooibereik en verschillende metingen van octrooiwaarde. In mijn derde studie vind ik sterke steun voor mijn hypothetische positieve relatie, tussen de openbaarmakingskwaliteit van octrooien (*toereikendheid van de openbaarmakingsdimensie* van octrooikwaliteit) en octrooiwaarde in de markten voor technologie en financiën.

Originaliteit/waarde: De studie levert een theoretische bijdrage door (a) de opkomende ex-ante theorie van octrooiwaarde te bevorderen door een conceptueel model uit te werken dat de verschillende dimensies van octrooikwaliteit en octrooiwaarde met elkaar in verband brengt en (b) bepaalde relaties te testen die de ex-ante theorie in een empirische setting ondersteunen. De studie draagt bij aan de praktijk door te informeren over de substantiviteit van het effect van bepaalde dimensies van octrooikwaliteit op de octrooiwaarde. De studie draagt bij aan het beleid door te suggereren dat (a) innovators kunnen worden gestimuleerd om octrooiaanvragen van hoge kwaliteit in te dienen die de efficiëntie en reputatie van het octrooibureau zouden verbeteren, dat wordt bekritiseerd voor het verlenen van te veel octrooien van slechte kwaliteit, en (b) er zijn systemische problemen in de U.S. die octrooien van slechte kwaliteit (of te brede reikwijdte) in de eerste plaats wettelijk toestaan, zelfs als deze octrooien voldoen aan de normen van octrooieerbaarheid vastgesteld door het octrooibureau. Ten slotte levert de studie empirische bijdragen door (a) de belangrijke concepten van octrooikwaliteit en octrooiwaarde te differentiëren, te definiëren en te relateren in een theoretisch kader, dat probeert het probleem van het verwarren van deze concepten in de bestaande empirische literatuur te overwinnen, en (b) het identificeren en valideren van een tot nu toe onbekende maar belangrijke dimensie van octrooibereik die is gebaseerd op de betekenis van bepaalde specifieke scope-gerelateerde termen in de octrooiclaims.

Table of Contents

Acknowledgments **2**

Summary **5**

Nederlandstalige Samenvatting **8**

Table of Contents **12**

List of Tables **15**

List of Figures **16**

1. Setting the Scene **17**

1.1 Common ground **17**

1.2 Complication **21**

1.3 Concern **24**

1.4 Course of Action **26**

1.5 Contribution **33**

1.6 Snapshot of Three Studies **38**

2 Study 1 .... **47**

Divide and Conquer: Relating Patent Quality and Value in a Conceptual Framework Based on a Systematic Review **47**

2.1 Introduction **48**

2.2 Theoretical Foundations **51**

2.3 Review Methodology and Publication-level Analysis **54**

2.3.1 The Protocol for Systematic Review 54

2.3.2 Publication-level Analysis 62

2.3.3 Patent Quality and Value Indicators 64

2.3.3.1 Temporal Partitioning of Patent Characteristics 64

2.3.3.2 Types of Pre-Grant Patent Characteristics as Patent Quality Indicators 65

2.3.3.3 Types of Post-Grant Patent Characteristics as Patent Value Indicators 68

2.4 Dimensions of Patent Quality and a Conceptual Model of Patent Value **70**

2.4.1 Dimensions of Patent Quality and Patent Value 70

2.4.2 Mapping Patent Quality and Value Indicators onto Corresponding Dimensions 75

2.4.3 Towards a Conceptual Model of Patent Quality and Value 79

2.5 Endogeneity, Validity, and Future Research Agenda **81**

2.6 Conclusions **85**

Appendix A **120**

3 Study 2 ..... **137**

The Economics of Patent Scope: An Empirical Study **137**

3.1 Introduction **138**

3.2 Theory And Conceptual Framework **144**

3.3 Research Strategy **145**

3.3.1 Data Collection 145

3.3.2 Operationalization 146

3.4 Results and Discussion **154**

3.4.1 Descriptive Analysis 154

3.4.2 Regression Models 159

3.5 Conclusions **164**

Appendix B **173**

4 Study 3 ..... **180**

Too Good to Ignore for Innovators: Disclosure Quality of Patents and Private Value **180**

4.1 Introduction **181**

4.2 Concepts, Theory, and Hypotheses **184**

4.3 Research Strategy **187**

4.3.1 Data Sources 187

4.3.2 Response Variables 189

4.3.3 Research Variable 189

4.3.4 Instrumental Variable 191

4.3.5 Control Variables 194

4.4 Results **199**

4.4.1 Descriptive Summary 199

4.4.2 Single-Stage Regressions 201

4.4.3 Two-Stage Regressions 204

4.5 Discussion **210**

4.6 Conclusions **212**

Appendix C **221**

5 Conclusions 226

5.1 Overall Context 226

5.2 Summary of the Findings 230

5.3 Overall Discussion of the Findings 232

5.3.1 Theoretical and Empirical Contributions 232

5.3.2 Validity and Reliability 233

5.3.3 Limitations and Future Research Directions 237

5.4 Managerial and Policy Implications 238

5.5 Concluding Thoughts 241

Complete Bibliography 245

List of Tables

N	Table No.	Chapter	Caption	Page
1	Table 1.1	Setting the Scene	Snapshot of Research Studies	39
2	Table 1.2	Setting the Scene	Publication Status of the Three Studies	40
3	Table 2.1	Study 1	Distribution of Literature Type and Paper Type in the Review	63
4	Table 2.2	Study 1	Patentability Standards at the Triadic Patent Offices USPTO, EPO, and JPO	72
5	Table A1	Study 1	Distribution of Papers Studying Patent Application and Examination-cum-Grant Characteristics	127
6	Table A2	Study 1	Papers Studying the Direct Measures, Estimates, and Indicators of Patent Value	129
7	Table A3	Study 1	Papers Studying the Dimensions of Patent Quality	131
8	Table A4	Study 1	Correspondence Between Codes and References for Papers	132
9	Table 3.1	Study 2	Composition of the Sample and Source	153
10	Table 3.2	Study 2	Summary Statistics	158
11	Table 3.3	Study 2	Correlation Matrix	159
12	Table 3.4	Study 2	Patent Scope and Patent Value	160
13	Table 4.1	Study 3	Composition of the Sample and Source	198
14	Table 4.2	Study 3	Summary Statistics	200
15	Table 4.3	Study 3	Results of Single-Stage Regressions	202
16	Table 4.4	Study 3	Results of Instrument Validity Regressions	206
17	Table 4.5	Study 3	Results of Two-Stage Regressions involving *Fog*	207
18	Table 4.6	Study 3	Results of Two-Stage Regressions involving *Kincaid*	209
19	Table C1	Study 3	Definitions of Controls for Instrumental Variable *EDS*	221
20	Table C2	Study 3	Distribution of Patents for *Technology*	222
21	Table C3	Study 3	Distribution of Patents for Origin	223
22	Table C4	Study 3	Correlation Matrix for Independent Variables	224
23	Table C5	Study 3	Correlation Matrix for Instrumental Variable and its Controls	225
24	Table 5	Conclusions	Summary of Research Studies	231

List of Figures

N	Figure No.	Chapter	Caption	Page
1	Figure 2.1	Study 1	Flow Diagram of the Screening Steps in the Systematic Literature Review	61
2	Figure 2.2	Study 1	Publication Trend of Papers in the Review	62
3	Figure 2.3	Study 1	An Organizational Map of Pre-Grant Patent Characteristic Types, Indicators of Patent Quality, and Patent Quality Dimensions	78
4	Figure 2.4	Study 1	An Organizational Map of Indicators and Dimensions of Patent Value	79
5	Figure 2.5	Study 1	Conceptual Model of Patent Value	81
6	Figure 3.1	Study 2	Trend in *Scope*	155
7	Figure 3.2	Study 2	Comparative Trend in *Scope* for Granted Patents and Pre-grant Publications	156
8	Figure B1	Study 2	Trend in *Scope* by NBER Technology Category	174

1. Setting the Scene

Alfred Nobel's wealth — the proceedings from which is used to award the Nobel Prizes — was the outcome of the monetization of several hundreds of industrial inventions that he had patented (Lindbeck, 1985). One could say, the most celebrated prize in science by humanity would not have existed without patents. This thesis is an attempt to understand the concepts of patent quality and patent value.

Based on a survey of the winners of the Academy of Management Journal best paper award, Grant and Pollock (2011) articulate that a good introduction elucidates the topic's impact; what scholars now know, what we do not know, and why that matters; and how the research contributes to an ongoing research conversation or starts a new conversation. Taking a cue from Grant and Pollock, the sections in this chapter follow the more intuitive and compelling "5-C" recommendation by Lange and Pfarrer (2017) for an empirical paper in the field of management; the five building blocks are the common ground, complication, concern, course of action, and contributions.

1.1 Common ground

Industrial innovations contribute significantly to the accumulation of societal knowledge and are engines of macroeconomic growth (Aghion & Howitt, 1992). A patent system is central to a nation's policies that promote technological progress. Patents are intellectual property assets that offer a grand bargain to innovators by providing a temporary monopoly through exclusionary rights in exchange for public disclosure of inventive knowledge to facilitate technological diffusion.

Take the example of the Airplane invention (Fromer, 2008). The Wright Brothers patented their flying machine — a glider with wings that warped in flight to turn and navigate. Standing on the shoulders of the Wright Brothers, inventors innovated further by designing the modern-day commercial jet plane, sea plane, and surveillance aircraft. As per Sachs (2018), in the pharmaceutical industry, it costs over a billion dollars to develop and launch a new drug; the process is fraught with considerable risk and typically takes anywhere between 12 and 16 years from inception to regulatory approval. The COVID-19 pandemic has prompted a global emergency; vaccine developers have been able to leverage decades of prior work on vaccine technology and find effective ways to chop several years off the drug development timeline by significantly reducing the time for regulatory approvals (see Amanpour, 2021).

Most drugs, once developed, are easy to imitate. Protection of inventions by patent rights enables innovators to recoup the investments made in the R&D of innovations without the fear of blatant imitation by rivals and associated losses. Patents not only motivate the supply of inventions but also encourage transactions of information between institutions — a university looking to license its discovery to a firm for further development or a start-up pitching its technology to a venture-capital firm to acquire funds; exchanging critical information without intellectual property protection by the benefactor might result in misappropriation of the value from the information by the beneficiary (this is explained in the highly influential paper by Arrow, 1962).

Patents are of extensive interest to managers, economists, and management scholars because they serve as rich sources of qualitative and quantitative information on technological change (see Scherer, 1983). As Gittelman (2008) comments, patent data have increasingly played a central role in empirical research on innovation; study of knowledge in and across organizations is a key theme in management research for which patent data provides a wealth of valuable information. Several reasons can be attributed to a burgeoning academic interest in patents such as the relative ease of availability of patent data, explosive patenting in the 21st century, the significance of patents to innovators and society, and the multi-disciplinary nature of patents as information sources. The topic of *patent value* has generated longstanding scholarly interest (Ribeiro & Shapira, 2020) and has been critically reviewed by Allison (2018) and van Zeebroeck and van Pottelsberghe de la Potterie (2011b). Baron and Delcamp (2012) inform that while the definition of patent value has been adopted rather consistently in literature, a binding definition for *patent quality* has remained elusive.

In this thesis composed of three principal studies, the first study explores the concepts of patent quality and patent value and the relationship between the concepts based on theoretical foundations using a systematic literature review (SLR). The second and third studies are investigations of the association between certain unexplored dimensions of patent quality and patent value. Specifically, the second study focusses on the *patent scope* as a subdimension of patent quality, and the third study zooms into the *sufficiency of disclosure* dimension of patent quality.

Patent scope and patent duration are policy variables of great economic significance; several influential theoretical papers demonstrate how the different combinations of these two variables maximize social welfare. Gilbert and Shapiro (1990) define patent "breadth" as the ability of the patentee to raise the price for a single patented product and find that an optimal patent policy would require the patents to have an infinite life and narrow breadth. Defining patent scope as the region of differentiated product space protected by the patent, Klemperer (1990) concurs with Gilbert and Shapiro under certain conditions but finds that broad-scoped, short-lived patents are optimal under different conditions. By measuring patent scope as the flow of profits earned by an innovator, Gallini (1992) (also discussed in Gallini & Scotchmer, 2002) shows that social surplus is maximized when patents are broad and patent life is adjusted to achieve the desired patent award.

In empirical studies, the patent scope is mostly measured (see Novelli, 2015) based on the number of claims (Tong & Frame, 1994) and the number of examiner-assigned technology classes (Lerner, 1994). More recent measures include the average number of words per independent claim (Kuhn & Thompson, 2019; Marco, Sarnoff, & DeGrazia, 2019) and that derived based on the complex dependencies among the patent claims (Wittfoth, 2019). The claim is a patent's most important element as it contains the information most relevant to the scope of the invention; any direct measure of patent scope would have to be based on the claims (see Cotropia, 2005; Marco et al., 2019). Further, scope measures based on patent claims provide the additional benefit of being able to study the changes in scope between a granted patent and its pre-grant publication; this change can be studied to get insights into the patent examination process (Marco et al., 2019).

Two major theories of patents — the incentive theory and disclosure theory — explain the role of patents in the economy (Eisenberg, 1989; Mazzoleni & Nelson, 1998; Williams, 2017). The more familiar (and the more extensively studied) incentive theory posits that the prospect of a patent motivates R&D investments and promotes innovations. According to the central tenet of the disclosure theory, patent disclosures facilitate the diffusion of the technical information underlying patented innovations among the public and help in stimulating research ideas externally.

Empirical literature embedded in the disclosure theory of patents addresses three important aspects of disclosures — timing, accessibility, and "quality". Studies find that faster patent disclosures decrease duplicative research efforts by competitors (Lück, Balsmeier, Seliger, & Fleming, 2020) and increase follow-on innovation (Baruffaldi & Simeth, 2020; Hegde, Herkenhoff, & Zhu, 2018; Kim & Valentine, 2021; Okada & Nagaoka, 2020). The association between the accessibility of patent disclosures and subsequent (external) innovation is also positive (Büttner, Firat, & Raiteri, 2022; Furman, Nagler, & Watzinger, 2021). Dyer, Glaeser, Lang, and Sprecher (2020) report a positive effect of the disclosure quality of patents on follow-on (external) innovation; within the nanotechnology field, Sun (2018) finds no significant association between the disclosure quality of patents and knowledge flows. Reitzig (2004a) studies the association of patent disclosure attributes with the likelihood of opposition to European patents. Niidome (2017) investigates the correlation between the length of disclosure in Japanese patents and patent validity outcomes. The survey findings by Oullette (2012) support the premise that patent disclosures have informational benefits to readers across a range of technologies.

1.2 Complication

Notwithstanding the longstanding and flourishing academic interest in patent quality as well as patent value, the problem of confounding these concepts is prevalent in the research literature (see de Rassenfosse & Jaffe, 2018); this widespread inconsistency in the conceptualizations gives an impression that the relationship between these concepts is correlational (i.e., we do not know which factor is the antecedent and which one is the consequence), or worse, they probably mean the same thing. In a recent paper, Higham, de Rassenfosse et al. (2021) posit that patent quality is a multidimensional construct but do not explain the multidimensionality further. This problem in the conceptualization of patent quality and value as well as the lack of knowledge on how the two concepts can be related is the motivation for the first study.

Cotropia (2005) comments that notwithstanding the high relevance of claims to patent scope, they are written using terms that in isolation are useless as they must be interpreted (or the meaning known) to make sense. Williams (2017) informs that the difficulty in interpreting patent claims is the reason why patent scope as a concept is challenging to define and measure and why the traditionally used scope measures such as the number of claims and the number of words per claim have limited applicability. Though Marco, Sarnoff et al. (2019) and Kuhn and Thompson (2019) independently explicate the number of words per independent claim as an indicator of patent scope along the language dimension of claims, admittedly, the measure is inconsistent with the rationale underpinning its construction that the *longer* the claims (or the more the number of words in a claim), the *narrower* the claim scope. Specifically, for a subset of patents in the chemicals, drugs, and biotechnological domains that are frequently drafted using a special Markush language (see Simmons, 1991), *shorter* claims are associated with a *narrower* scope.[1] This problem in the lack of understanding of how patent scope — a subdimension of patent quality — can be measured based on claim interpretation and what is the association between the corresponding measure of patent scope and patent value is the motivation for the second study.

Although patent disclosures enlarge the storehouse of knowledge and have the potential to benefit the public in different ways, they are often criticized as being incomplete, opaque, and ambiguous (for example, see Eisenberg, 1989; Seymore, 2010), which casts a shadow over their social value promise. It is also known that innovators disclose information less efficiently in patents primarily for the fear of knowledge spillover among rivals (Hughes & Pae, 2015). Though knowledge spillover is inevitable, what is not fully appreciated in the empirical literature is that patent disclosures can *benefit* the disclosing innovators in certain ways, which is the premise of one aspect of the disclosure theory of patents (Mazzoleni & Nelson, 1998) and one aspect of the emergent ex-ante theory of patent value (Perel, 2014) which is elaborated in the first study.

[1] To explain this logic, consider the set of hypothetical Markush claims: (1) A process employing a catalyst selected from the group consisting of iron, cobalt, and nickel; and (2) A process employing a catalyst selected from the group consisting of iron, cobalt, nickel, and zinc. Though claim (2) has more words than claim (1), it is also broader in scope as it includes an additional possibility of zinc as a catalyst.

Tangentially related to the third study, Hegde and Luo (2018) find that faster patent disclosures increase the speed of licensing deals. Another study suggests that the presence of patent disclosures during negotiation in technology markets does not increase the chance of negotiation success (de Rassenfosse, Palangkaraya, & Webster, 2016). Heely, Matusik, and Jain (2007) find that patents reduce information asymmetries in industries where the link between patents and inventive returns is transparent, which reduces the underpricing of initial public offerings in the markets for finance. In the third study, which differs from what is known in the literature as discussed above, the focus is on the link between the *quality* of patent disclosures (specifically, the *sufficiency of disclosure* dimension of patent quality) and the likelihood of success of patent transactions in the markets for technology on one hand and the stock prices of listed firms in the markets for finance on the other hand.

In summary, extant literature does not provide a complete understanding of the nature of the relationship between the quality and value aspects of a patent. Further, there is a lack of knowledge of how patent scope, a critical policy variable, can be measured based on the meaning of words in the patent claims. Furthermore, there is a virtual lack of empirical evidence on how patent disclosures can benefit the disclosing innovators in the contexts of markets for technology and finance. The central motivation of this thesis is to use these complications as the bases to find answers to the following research questions:

1)
   a) what are the dimensions of *patent quality*? and
   b) how is *patent quality* linked to *patent value*?

2)
   a) how can *patent scope* be measured based on claim interpretation? and

b) what is the extent of the relationship between *patent scope* measured based on claim interpretation and *patent value*?

3) what is the extent of the relationship between the *quality* of patent *disclosure* and the *private value* of a patent in the markets for technology and finance?

1.3 Concern

Love, Miller et al. (2019) posit that patent quality and patent value are distinct concepts; this distinctiveness is consistent with the argument that quality and value, in general, are unique aspects (see Reeves & Bednar, 1994). De Rassenfosse and Jaffe (2018) argue that patent quality and value are likely to be positively correlated. Patent value and patent quality as theoretical constructs should not only be conceptually distinct but also capable of being linked like value and quality are in other areas of business and management research. For instance, in an influential paper in the field of marketing, Zeithaml (1988) establishes a structural relationship between the value and quality aspects of a product from a consumer's perspective; the author asserts that the lack of clear differentiation between the constructs in *any field* limits research on these and the linkages between them. The emergent ex-ante theory of patent value by Perel (2014) proposes a *positive* and *direct* relationship between patent quality and value.

A relationship between patent quality and value that is theoretically grounded essentially establishes patent quality as an important determinant of patent value; in the spirit of Zeithaml (1988), further exploration of these concepts and the relationship between them would help in organizing the idiosyncratic considerations of the concepts in a burgeoning and convoluted subject of empirical research in innovation economics. Such an organized study would in-turn benefit the major stakeholders in patents such as the innovators, public, and patent policy makers who would have a clearer understanding of how to assess the patent quality and how to improve it (for innovators) to maximize the value of patent portfolios the creation of which require significant capital expenditure.

Since the statutory duration of a patent is fixed, the role of patent scope as a policy lever deserves more empirical attention (see Merges & Nelson, 1990). Marco, Sarnoff et al. (2019) inform that though all patent systems use legal doctrines to regulate patent scope, the discussion of scope as a policy instrument remains largely theoretical. Kitch (1977) explains the scope of a patent as embodied in the claims would be broader than that of the underlying invention since the former represents an abstraction and generalization of an indefinitely large number of real-world objects, and he argues for broader patent scope for inventions with more future "prospects" as such a patent would enable the innovator to continue with the development of the invention without the fear of external encroachment (also see Merges & Nelson, 1994). Notwithstanding the nature of the invention, an innovator would always want the broadest possible scope for a patent at grant; the role of the patent office here becomes critical which uses its discretionary powers to decide how broad this scope should be (Merges & Nelson, 1990). Marco, Sarnoff et al. (2019) inform that patents issued with an *overly* broad scope relative to the inventive contribution are reflective of "poor" quality and these could seriously hurt subsequent innovation efforts by competitors and undermine the role of the patent system in the economy.

Essentially, given the high importance of patent scope as a concept to innovators and the patent system, the issue of lack of knowledge in the assessment of patent scope based on claim interpretation needs to be addressed to (a) inform innovators on a strategy to increase the quality of their patents by broadening the patent scope which would eventually increase the value of their patent portfolios and (b) provide a measurement tool to examiners at the patent office to address the longstanding policy debate of granting too many patents of overly broad scope (or poor quality).

Knowledge spillover among the competitors and public from patent disclosures of an innovator is inevitable and well understood. However, in at least two contexts such as the transactions of patents in the markets for technology where potential licensees of a patent learn about the opportunity to license through patent disclosures (Levin et al., 1987) and the markets for finance where potential investors look for signals about the quality of inventions based on the information in patent disclosures (Long, 2002), innovators theoretically stand to benefit if they enhance the quality of their patent disclosures. An empirical evidence-based appreciation by innovators of such benefits can motivate them to address some of the issues associated with the poor quality of patent disclosures that currently plagues the patent systems. As discussed later (see the subsection on contributions), such a behavioral change by innovators has significant implications for practice, policy, and the public.

1.4 Course of Action

In the first study, I conduct an SLR (see Kraus, Breier, & Dasí-Rodríguez, 2020) to consolidate the findings on patent quality and value in hundreds of relevant papers (340 to be specific) spanning the diverse research disciplines of management, economics, finance, accounting, law, sociology, science, and technology.

The SLR is grounded in the emergent ex-ante theory of patent value by Perel (2014) (henceforth, the ex-ante theory) which proposes a positive and direct relationship between patent quality and value. Consistent with Guerrini (2013) who posits that a reasonably acceptable definition for patent quality would depend on the perspectives of the major stakeholders in patents — the patent offices, courts, patentees, and public — the ex-ante theory adopts a *regulatory* (of the patent office) definition for patent quality, which is *the conformance of a (granted) patent to the statutory standards of patentability*. The regulatory approach has merit because (a) the measurement of patent quality by this method is objective (Graf, 2007), (b) the approach is consistent with the argument that quality, in general, is measured most precisely when defined as conformance to specifications (see Reeves & Bednar, 1994), and (c) the approach is advantageous compared to alternatives such as the ex-post validity approach that involves measuring patent quality based on the validity of an issued patent (Graf, 2007) and the economist's notion (Hall & Harhoff, 2004) according to which a good quality patent is the one that protects a good idea (specifically, an invention) that is commercialized.

The advantages of the regulatory approach for patent quality stem from the fact that both the alternative approaches discussed above apply to substantially smaller sample sizes as only a small proportion of the universe of patents are commercialized (Higham et al., 2021) or challenged on validity grounds either at a patent office (Hall & Harhoff, 2004) or in a court (Higham et al., 2021). Due to the methodological issues in having to deal with small, disparate samples of patents, the findings from patent quality studies based on these alternative approaches are less generalizable (Love et al., 2019). Further, the regulatory lens adopted by the ex-ante theory allows for patent quality to be assessed the moment a patent is granted; this offers an additional benefit to the stakeholders in patents of being able to appraise the patent quality and to an extent, predict patent value *much earlier* in time along a patent's normal life.

The information gleaned from the analysis of 340 relevant papers in the SLR yields a text corpus of patent characteristics based on idiosyncratic considerations of "patent value" or "patent quality". The information is synthesized by first partitioning the patent characteristics along the temporal dimension *exclusively* into those associated with patent quality or patent value; based on the ex-ante theory, the event of the patent grant is the cut-off point that allows for this partitioning. This temporal partitioning results in the first level of organization of patent characteristics into those associated with patent quality (pre-grant characteristics) and patent value (post-grant characteristics).

The dimensions of patent quality and patent value are then delineated and linked in a conceptual model. To understand the dimensions of patent quality from a broader perspective, a comparative analysis of the requirements for patentability in the three *major* patent offices of the world known as the 'triad' (Frietsch & Schmoch, 2010) – the patent offices in the U.S, Europe, and Japan is conducted. The objective of this exercise is to conceptualize patent quality broadly so that it can be adopted in empirical investigations of patent quality in any jurisdiction. Consistent with extant literature, the study also explicates two dimensions of patent value. The patent (pre-grant as well as post-grant) characteristics are classified into different subtypes and these subtypes are mapped on the corresponding dimensions of patent quality or value, resulting in an elaborated conceptual model. This model also includes factors at the assignee-level as well as other contextual factors that could affect the patent value as control variables.

The second study primarily includes data from the most representative and widely studied patent office in the world — the USPTO. Consistent with the literature in the field of innovation economics, utility patents are chosen as the sample and a granted patent is the unit of observation and analysis. The grant year range of the patents in the sample is 2001-2014. The data is collated from three sources - the USPTO, Clarivate, and PatentsView. The USPTO periodically releases patent datasets for academic research; among them, the following are used:

(1) Patent Examination Research Dataset (Graham, Marco, & Miller, 2015) containing the information on the examination of US patents published through 2019;

(2) Patent Litigation Dataset (Marco, Tesfayesus, & Toole, 2017) containing the litigation data of US patents obtained from unique district court cases filed during 1963-2016;

(3) Patent Claims Research Dataset (Marco, Sarnoff, & deGrazia, 2016) containing the information on the claims for US patents granted during 1976-2014 and US applications published during 2001-2014; and

(4) Patent Assignment Dataset (Marco, Myers, Graham, D'Agostino, & Apple, 2015) comprising information on patent reassignments and security interest agreements recorded at the USPTO since 1970.

PatentsView is a data visualization, bulk download, and analysis platform supported by the USPTO that I primarily use to obtain the data on citations and the National Bureau of Economic Research (NBER) technology category of patents (Hall, Jaffe, & Trajtenberg, 2001). Clarivate is used to extract information on the family composition (see Martinez, 2011) of the patents in the sample. The patents obtained from these multiple sources is merged by patent number as the common identifier and cleaned to remove the records with missing or erroneous values; the preliminary research sample (prior to construction of the research variable) has around 2.4 million patents. As supplementary data, the research further uses the estimates of the U.S. dollar value of patents assigned to publicly listed firms from Kogan, Papanikolaou et al. (see 2017) for a subset of around one million patents in the research sample.

In the second study, I refer to the U.S. patent statute's rules on claim interpretation (MPEP § 2111 USPTO, 2020c) to identify terms in patent claims that specifically relate to patent scope to construct the research variable. Essentially, the claim terms 'comprising', 'including', 'containing', and 'characterized' are open-ended as each of these terms is interpreted to be inclusive of the additional elements *not* specified in a claim, whereas the claim term 'consisting' is close-ended as it's interpreted to exclude elements not specified in a claim. The validity of the open-ended scope terms in the research variable construction stems from the fact that the U.S. patent doctrine (MPEP § 2111 USPTO, 2020c) cites several case laws wherein the interpretation by the courts of these terms in the claims is unambiguous and consistent with that by the patent office. Notably, these terms have particularly established meanings among practitioners based on decades of their consistent usage in claims drafting (see Menell, Powers, & Carlson, 2010).

To construct the research variable *Scope*, the sum of the frequencies of occurrence of each of the open-ended scope terms in the independent patent claims in the research sample of over two million U.S. patents is first obtained using a text-mining algorithm in R statistical programming language. Then, the average (arithmetic mean) of this sum per independent claim is taken. To authenticate the text-mining method, a random subset of 100 patents from the research sample is drawn and the algorithm-generated frequencies of both the open-ended and close-ended scope terms are crosschecked against the corresponding actual counts. The algorithm-generated measures match with the actual in 99 out of the 100 patents; this finding validates the text-mining technique used for the measurement of patent scope. To establish the nomological validity of the scope measure, based on the proposed positive relationship between patent quality and patent value by the ex-ante theory, the relationship between patent scope (as a subdimension of patent quality) and several established measures of patent value such as the number of self-citations to a patent, the estimated dollar value of a patent at issuance, and the incidence of litigation, reassignment, or collateralization of a patent is tested.

The third study uses the data described for the second study and supplements it with the data from the current release of the USPTO Office Action Research Dataset for Patents (in short, the office actions dataset) (Lu, Myers, & Beliveau, 2017). This dataset consists of information from 4.4 million office actions mailed from 2008 to 2017 to the applicants of 2.2 million unique patent applications. The supplementary data is used to conduct an instrumental variable analysis.

The third study deals with the quality of patent disclosures. As per Article 29 of the WTO (2021), the *enablement* of patents is the extent to which an applicant for a patent discloses the invention in a manner that is *sufficiently clear* and complete for the invention to be practiced by a skilled artisan. As enablement is the only uniformly applicable disclosure requirement in patents across major geographies (see Ouellette, 2012), this study considers disclosure quality as conceptually equivalent to the quality of enablement. Consistent with Seymore (2010) and Dyer et al. (2020), this study links the quality of patent disclosures, particularly their *clarity*, to their ease of *readability*. The study adapts the definition of readability from Loughran and McDonald (2014) as the ability of the reader of a patent disclosure to comprehend relevant information in the disclosure.

In a seminal paper, Levin et al. (1987) suggest a link between the quality of information disclosure and the private value of patents in technology markets by providing an example that potential licensees of a patent may learn about the opportunity to license through the “announcement” effect of patent disclosures. Mazzoleni and Nelson (1998) posit that in one version of the disclosure theory of patents, the information disclosed in a patent would benefit an innovator in certain ways, particularly when the innovator cannot exploit all the uses of the patented invention. In such cases, the extent to which the information disclosed in a patent can attract the attention of an external party, say in the technology markets where patents are licensed or reassigned, would determine the extent to which the innovator can appropriate value from the patent through such external means. Concurring with Mazzoleni et al. (1998), citing the famous Arrow's paradox (1962), Arora and Ceccagnoli (2006) suggest that the quality of information disclosed in a patent is a factor that determines the likelihood of licensing of a patent.

Agrawal, Cockburn, and Zhang (2015) inform that information asymmetry is a factor that imposes transaction costs and causes the failure of markets for ideas. Since information asymmetry and disclosure quality are inversely related (Brown & Hillegeist, 2007), in technology markets, a higher quality of information disclosure in patents would lower the information asymmetry between the trading partners. A reduced information asymmetry would then facilitate transactions in these markets to a greater extent, which would increase the value of the patent to the patentee.

Long (2002) argues that a patent's private value may not *just* be determinable by the rents obtained from the commercial use of the patent in a product market. Innovators can also benefit through other means, for example, by publicizing the information about the invention in patents; this value corresponds to the non-product market value of patents. Long posits that the information disclosed in patents may signal to potential investors about the ingenuity or value of the patenting firm and enable them to make informed investment decisions. In a product-innovation setting, Anton et al. (2003) surmise that enabling patent disclosures can convey positive signals about the disclosing firm and attract investment in capital markets.

It is noteworthy that the relationship between the quality of patent disclosure and the private value of patents in the markets for technology and finance emerges from the ex-ante theory of patent value which grounds this thesis.

In the third study, consistent with the central role of patent disclosures in information dissemination, the descriptive sections of patent disclosures — the non-claim, full-text of patents — are considered for variable construction (see Fromer, 2008). In the research setting, the full text of a sample of over two million U.S. patents is analyzed. The disclosure quality is measured as the ease of readability of patents following Dyer et al. (2020). Consistent with the research hypotheses, two measures of appropriation of value from patents are studied: estimates of patent value based on the stock market reactions to patent grants (Kogan et al., 2017) and the likelihood of ownership transfer (reassignment) of patents (Serrano, 2010). To facilitate causal inference, an instrumental variable approach is adopted akin to Dyer et al.; the variation in the propensities of patent examiners to reject patent applications that do not meet the disclosure requirements of patentability is measured as an exogenous variable to instrument for the quality of patent disclosures.

1.5 Contribution

Each of the three studies makes several contributions to empirical literature, theory, policy, and practice.

The first study (SLR) contributes to theory by advancing the ex-ante theory of patent value using the research approach of theoretical elaboration (Fisher & Aguinis, 2017) that encompasses conceptualizing and executing empirical research using pre-existing conceptual ideas or a preliminary model as a basis for developing new theoretical insights. Theoretical elaboration involves contrasting, specifying, or structuring theoretical constructs and relations to account for and explain empirical observations. The SLR is grounded in the emergent ex-ante theory of patent value (Perel, 2014) that posits a positive and direct relationship between patent quality and patent value; the ex-ante theory proposes four dimensions for patent quality based on the patentability standards of the USPTO: subject matter eligibility, utility, novelty and non-obviousness, and clarity and definiteness. The SLR advances an elaborated conceptual model which relates patent quality and value in a conceptual framework. Specifically, the SLR (a) provides a general definition for patent quality based on the standards of patentability adopted by the three major (triadic) patent offices of the world in the U.S., Europe, and Japan, (b) delineates patent quality into four dimensions – *subject matter, utility, non-obviousness or inventive step*, and *sufficiency of disclosure*, and (c) maps the different types of indicators of patent quality and value obtained from the synthesis of 340 relevant papers in the review on to the corresponding patent quality or value dimension.

The empirical contribution from the first study stems from the distinction and organization of the concepts of patent quality and value in a model which changes the dominant notion held by the scholarship that these concepts can be used interchangeably or they mean the same thing. The first study also has concerted implications for practice, policy, and society. A theoretically grounded understanding of how a patent's quality is linked to its value would strengthen the incentives of innovators to file high-quality patent applications and weaken their incentives to file low-quality patent applications (Perel, 2014). Both these factors would enhance the value of patents for an applicant and minimize the costs associated with the rejection of poor-quality applications by the patent office. A reduction in the incidence of poor-quality patents in a patent system would improve the efficiency and reputation of the patent office as patent examiners would be spending less time on substandard patent applications and more time on high-quality (and presumably, more societally beneficial) patent applications. Further, high-quality patents would be less subject to costly and cumbersome litigation (or other legal) proceedings related to patent rights, which would benefit all the parties to such transactions (see Wagner, 2009).

The second study makes four main contributions. First, it contributes to the literature on innovation economics by explicating a valid, stable, and complementary measure of patent scope. My measure is valid on three counts: (a) I construct the measure from certain specific, traditionally used scope-related terms by practitioners in the patent claims that are identified based on their consistent construal by the patent office and the courts in the U.S., (b) on a random sample of 100 patents, a manual check reveals that value of the scope measure from the text mining algorithm matches with the actual value in 99 patents, and (c) consistent with theoretical predictions, I find the scope measure is positively and significantly ($p < .05$) associated with multiple indicators of patent value. The stability of the measure is indicated by the nonfluctuating sign of the coefficients in the regression models. The scope measure is also complementary to perhaps the most reliable and direct patent scope measure, the number of patent (independent) claims, as the former captures the variation in patent scope along the hitherto untapped but very important dimension of claim interpretation.

Second, it makes an empirical contribution by identifying and validating a hitherto unknown yet important subdimension of patent scope which is related to the meaning of certain words in the claims of patents. Unravelling of this subdimension opens up an intriguing research opportunity in the future which could lead to more precise measures of patent scope, which happens to be an important patent policy variable that has received scant empirical attention.

Third, it contributes to management practice in multiple ways. The trend analysis of the scope measure indicates that innovators use the scope-related terms in patent claims to broaden the patent scope in two stages: strategically at the patent application stage and tactically during the patent examination whilst the patent examiners (consistent with the standards of patentability) typically curtail the overall scope of the patent by decreasing the number of independent claims or increasing the number of words in an independent claim. This finding would enlighten managers on the strategic and tactical usage of the scope-related terms in the patent claims to maximize the overall scope of a patent at issuance. The effect of the scope measure on the private value of patents is also economically significant. For example, on a subset of patents assigned to publicly listed firms in my sample, all things remaining the same, an increase in one open-ended scope term per independent claim corresponds to an 8.5 percent increase in the estimated dollar value of the patent. The knowledge of my scope measure would also enable a reasonably accurate assessment of patent value and facilitate well-founded decisions on patents such as the licensing, transfer, or collateralization of the patents in the technology markets.

Fourth, it contributes to the patent policy debate in the U.S. on the quality of issued patents (see Marco et al., 2019). The trend analysis of the scope measure during the grant year range of 2005-2014 suggests that (a) for granted patents, the measure is *increasing*, and (b) the measure for a granted patent *exceeds* that for its pre-grant publication in each grant year. This finding contrasts with that of Marco, Sarnoff et al. (2019) for the other claim-based scope measures such as the number of independent claims or the average number of words per independent claim; the authors attribute the observation to the “stringency” of patent examination following the various patent quality improvement initiatives at the USPTO since 2004. The contrasting finding stands to invigorate the patent quality debate. Since the USPTO explicitly lays down rules on how to interpret the scope-related terms in the claims, the presence of these terms in patents plausibly justifies the patentability standards. These findings are suggestive of systemic issues in legally authorizing patents with an overly broad scope.

The third study advance four main contributions. First, it extends the empirical adequacy of the disclosure theory of patents to contexts where the quality of technical information in patent disclosures benefits the patent holders in the markets for technology or finance; the results provide strong support to the hypotheses of a positive relationship between the quality of enabling disclosures and private value of patents in these contexts. Second, the study contributes to empirics in innovation literature by challenging the prevalent notion that a higher quality of information disclosure in patents is detrimental to the innovator because such disclosures would increase the diffusion of knowledge embodied in patents among the public (including the competitors) and hence reduce the potential returns from the patented innovations. Our results provide preliminary empirical evidence that innovators can benefit from high quality disclosures in certain contexts such as the markets for finance or technology.

Third, from a policy standpoint, the results suggest that enablement as a patent policy variable is beneficial to patent applicants in certain ways; an appreciation of this benefit should incentivize patent applicants to file patent disclosures of high quality, which would help in removing poor quality patents from the system at source and hence improve the efficiency and reputation of the patent office. This implication is important because the patent office is often criticized to issue too many patents of poor quality (see Lemley & Sampat, 2008).

Fourth, the study also contributes to practice by informing on the substantivity of the association between disclosure quality and the private value of patents in the markets for technology or finance. Specifically, for patents owned by publicly listed firms, *ceteris paribus*, an *increase* in the readability of patent disclosures by 10 percent corresponds to an *increase* in the patent value at grant, which is estimated based on the reactions to patent grants by the firm's investors in the stock markets, by 18 percent, and for patents assigned to firms, a similar increase in readability corresponds to an *increase* in the likelihood of reassignment of the patents in the markets for technologies by 7.4 percent.

The subsequent chapters in this thesis follow a logic. Chapter 2 (Study 1) provides a full account of the SLR and explicates a conceptual model linking the various dimensions of patent quality and value. Chapter 3 (Study 2) describes how to identify and measure a novel subdimension of patent scope based on the semantics of patent claims and tests the hypothesized positive relationship between this construct and patent value using the conceptual model from Chapter 2 as the basis. Using the conceptual model from Chapter 2 (and consistent propositions from the disclosure theory and signalling theory of patents), Chapter 4 (Study 3) tests the relationship between the quality of patent disclosure and the private value of patents in the contexts of the markets for technology and finance. Finally, Chapter 5 presents the overall conclusions of the thesis.

1.6 Snapshot of Three Studies

The research questions, design, methodology, and hypotheses (where applicable) in the three studies are shown in Table 1.1. The publication status of the three papers is shown in Table 1.2.

Table 1.1 Snapshot of Research Studies

Study	First	Second	Third
Research Question(s)	1. How are patent quality and value related in a conceptual framework? 2. What are the dimensions of patent quality and value? 3. How are the different indicators of patent quality and value related to the different and respective dimensions of patent quality and value?	1. How to measure patent scope based on claim interpretation? 2. What is the effect of this patent scope measure on the private value of patents?	For the holder of a patent, what is the effect of the quality of the patent disclosure on the appropriation of value from the patent in the markets for technology or finance?
Methodology	SLR	Quantitative	Quantitative
Design	Papers from SLR (publication date range 1979-2022)	USPTO patent examination data (grant year range 2001-2014)	USPTO patent examination data (grant year range 2001-2014) and patent prosecution data (application year range 2006-2014)
Technique	Content analysis	Regression analysis	Regression analysis
Hypotheses	None	H: *Ceteris paribus*, the broader the patent scope the higher the private value of the patent	H1: For a patentee, *ceteris paribus*, the higher the quality of disclosure in a patent, the greater the appropriation of value from the patent in the markets for technology. H2: For a patentee, *ceteris paribus*, the higher the quality of disclosure in a patent, the greater the appropriation of value from the patent in the markets for finance.

Table 1.2 Publication Status of the Three Studies

Study	Journal/ Conference Paper	2021 Impact Factor	Current Status
1	*International Journal of Management Reviews*	8.958	The first round of major revisions completed and outcome expected
2	*Research Policy*	9.473	Major revise and resubmit decision from referees
3	*R&D Management Conference*	-	The preliminary manuscript was presented at the R&D Management Conference, University of Trento, Italy in July 2022. Following the conference, the revised manuscript is under development for a suitable journal

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2 Study 1

Divide and Conquer: Relating Patent Quality and Value in a Conceptual Framework Based on a Systematic Review

Abstract

Patents as intangible assets are subjects of burgeoning empirical research. There is limited knowledge of how patent quality and patent value can be conceptualized, distinguished, and related. Distinguishing these concepts and relating them in a theoretical framework would enable the assessment and improvement of patent quality, which has implications for all the stakeholders in patents. I ground this study in the emergent ex-ante theory of patent value and conduct a systematic review of 340 papers that investigate patent quality or value. Based on a comparative analysis of the patentability standards adopted by the patent offices in the U.S., Europe, and Japan, I delineate four dimensions of patent quality – subject matter, utility, non-obviousness or inventive step, and sufficiency of disclosure. My study contributes to theory by providing an elaborated conceptual model that relates the different dimensions of patent quality and patent value and maps the different types of indicators of patent quality and value onto the corresponding patent quality or value dimensions. My study suggests that patent policy makers can incentivize innovators to file patent applications of high quality, which would reduce the incidence of poor-quality patents in the system and improve the efficiency and reputation of the patent office.

Keywords: patent quality, patent value, ex-ante theory, systematic literature review, conceptual model

2.1 Introduction

A patent system is central to a nation's policies that promote technological progress. Patents offer a grand bargain to innovators by providing a temporary monopoly through *exclusionary rights* — the right to exclude others from making or using the patented invention — in exchange for public disclosure of the patented invention to facilitate the diffusion of codified knowledge among the public. Rich (1993) informs that the temporary monopoly is a fair *quid pro quo* for society to pay as a reward or inducement to the innovator who took the financial risk of developing a novel and unobvious invention and making it available to the society. The exclusive rights from holding a patent typically lasts for a period of seventeen years post grant of the patent. For the more interested reader, Dam (1994) provides a detailed account of the economic underpinnings of patent law.

Patents are of extensive interest to managers, economists, and management scholars and serve as rich sources of qualitative and quantitative information on technological change. The subject of patent value has generated longstanding scholarly interest (Ribeiro & Shapira, 2020) and has been critically reviewed by Allison (2018) and van Zeebroeck and van Pottelsberghe de la Potterie (2011b). A more recent paper (Grimaldi & Cricelli, 2020) provides a systematic review of "indexes" of patent value. Notable studies (non-review articles) on patent "quality" include those by Lemley (2001), Graf (2007), Lemley and Sampat (2008), Wagner (2009), van Pottelsberghe de la Potterie (2011), Guerrini (2013), Chien (2018), Love and Miller et al. (2019), and Higham, de Rassenfosse et al. (2021).

The problem of confounding the concept of patent quality with that of patent value is prevalent in extant research (see de Rassenfosse & Jaffe, 2018); this widespread inconsistency in conceptualization gives an impression that the relationship between these concepts is correlational (i.e., bidirectional), or worse, they probably mean the same thing. Baron and Delcamp (2012) inform that while the definition of patent value has been adopted rather consistently in literature, a binding definition for patent quality remains elusive.

Love, Miller et al. (2019) posit that patent quality and patent value are distinct concepts; this distinctiveness is consistent with the argument that quality and value, in general, are unique aspects (see Reeves & Bednar, 1994). De Rassenfosse and Jaffe (2018) argue that patent quality and value are likely to be positively correlated. Patent value and quality as theoretical concepts should not only be distinct but also capable of being linked like quality and value are in other areas of management research. For instance, in marketing, Zeithaml (1988) establishes a link between the quality and value aspects of a product from a consumer's perspective; the author asserts that the lack of clear differentiation between the constructs in *any field* limits research on these and the linkages between them. The emergent ex-ante theory of patent value by Perel (2014) proposes a *positive* and *direct* relationship between patent quality and value. A theoretically grounded understanding of what are the dimensions of patent quality and how the latter is related to patent value is important because it would help in an objective and reasonably accurate assessment of patent quality by all the stakeholders in patents and provide the innovators with a mechanism to improve the quality of their patents to increase the patents' value.

There exists a sizeable body of empirical literature on the topics of patent value and patent quality with idiosyncratic considerations of these concepts. A consolidation of the findings in these studies considering the emergence of the ex-ante theory of patent value (Perel, 2014) would provide a better understanding of the nature of the relationship between patent quality and value and set the agenda for future research on these topics. A systematic literature review is an effective interventional tool (see Kraus et al., 2020) to achieve these objectives. The current systematic review seeks to provide answers to three related research questions:

1. *How are patent quality and value related in a conceptual framework?*
2. *What are the dimensions of patent quality and value?*
3. *How are the different indicators of patent quality and value related to the different and respective dimensions of patent quality and value?*

This review contributes to the literature on patent quality and value by advancing the ex-ante theory of patent value (Perel, 2014) using the research approach of theoretical elaboration (Fisher & Aguinis, 2017). My elaborated model relates patent quality and value in a conceptual framework. Specifically, the review (a) advances a general definition for patent quality based on the standards of patentability adopted by the three major (triadic) patent offices of the world in the U.S., Europe, and Japan, (b) delineates patent quality into four dimensions – subject matter, utility, non-obviousness or inventive step, and sufficiency of disclosure, and (c) maps the different types of indicators of patent quality and value obtained from the synthesis of the relevant papers in the review on to the corresponding patent quality or value dimension.

The review has concerted implications for practice, policy, and society. A theoretically grounded understanding of how a patent's quality is linked to its value would strengthen the incentives of innovators to file high-quality patent applications and weaken their incentives to file low-quality patent applications (Perel, 2014). Both these factors would enhance the value of patents for an applicant and minimize the costs associated with the rejection of poor-quality applications by the patent office. A reduction in the incidence of poor-quality patents in a patent system would improve the efficiency and reputation of the patent office as patent examiners would be spending less time on substandard patent applications and more time on high-quality (and presumably, more societally beneficial) patent applications. Further, high-quality patents would be less subject to costly and cumbersome litigation (or other legal) proceedings related to patent rights, which would benefit all the parties to such transactions (see Wagner, 2009).

This review is organized as follows. In section 1.2, I explain the theoretical foundations for the review. In section 1.3, I describe the methodology to identify the relevant papers for the review and provide some findings at the publication level. In section 1.4, I provide a synthesis of the content from the relevant papers and discuss the different types of patent quality and patent value indicators, unfold the different dimensions of patent quality and patent value, map the different types of indicators of patent quality and value onto the corresponding dimensions, and present an elaborated conceptual model of patent value. In section 1.5, I discuss endogeneity, validity, and future research agenda, and in section 1.6, I conclude the paper.

2.2 Theoretical Foundations

This review adopts the research approach of theory elaboration (Fisher & Aguinis, 2017) that encompasses conceptualizing and executing empirical research using pre-existing conceptual ideas or a preliminary model as a basis for developing new theoretical insights. I ground this review in the emergent ex-ante theory of patent value (Perel, 2014) that proposes a positive and direct relationship between patent quality and patent value; henceforth, I refer to this theory as the 'ex-ante theory' for brevity. The ex-ante theory proposes four dimensions for patent quality: subject matter eligibility, utility, novelty and non-obviousness, and clarity and definiteness. The choice of the ex-ante theory to underpin this review is based on two main factors.

First, consistent with Guerrini (2013) who posits that a reasonably acceptable definition for patent quality would depend on the perspectives of the major stakeholders in patent quality: the patent offices, courts, patentees, and public, the ex-ante theory adopts a *regulatory* (of the patent office) definition for patent quality, which is the conformance of a (granted) patent to the statutory standards of patentability. The regulatory approach has merit because (a) the measurement of patent quality by this method is objective (Graf, 2007), (b) the approach is consistent with the argument that quality, in general, is measured most precisely when defined as conformance to specifications (see Reeves & Bednar, 1994), and (c) the approach is advantageous compared to alternatives such as the ex-post validity approach that involves measuring patent quality based on the validity of an issued patent (Graf, 2007) and the economist's notion (Hall & Harhoff, 2004) according to which a good quality patent is the one that protects a good idea (specifically, an invention) that is commercialized; the advantages of the regulatory approach stem from the fact that both the alternative approaches apply to substantially smaller sample sizes as only a small proportion of the universe of patents are commercialized (Higham et al., 2021) or challenged on validity grounds either at a patent office (Hall & Harhoff, 2004) or in a court (Higham et al., 2021). Due to the methodological issues in having to deal with small, disparate samples of patents, the findings from patent quality studies based on these alternative approaches are less generalizable (Love et al., 2019). Second, the regulatory lens adopted by the ex-ante theory allows for patent quality to be assessed the moment a patent is granted; this offers an additional benefit to the stakeholders in patents of being able to appraise the patent quality and to an extent, predict patent value *much earlier* in time along a patent's normal life.

The *presumption of validity* doctrine of a granted patent (EPO, 2021; for the doctrine in the three major patent offices of the world - the U.S, Europe, and Japan, see Oguri, 2007; 35 USC 282 USPTO, 2020a) is the core premise that lends credence to the regulatory perspective of patent quality. The fact that a patent is granted *only* after a substantive examination in correspondence with the patent applicant confers upon the granted patent a certain *minimum* quality (Popp, Santen, Fisher-Vanden, & Webster, 2013). Thomas (2002) posits that granted patents are valid patents that may be reliably enforced in court, consistently expected to surmount validity challenges, and dependably employed as a technology transfer tool.

Burke and Reitzig (2007) inform that the supposition of presumed validity of a granted patent may involve an element of uncertainty as patent assessments are made by humans (examiners) that can involve subjectivity in the decision-making processes. This uncertainty in the validity of a granted patent (due to factors attributable to the examiner or the patent system) would introduce an error in (regulatory) patent quality assessments. Historically, the United States Patents and Trademark Office (USPTO) has particularly been criticized for issuing too many patents of inferior quality (for example, see Lemley & Sampat, 2008); even recent studies continue to find an association between examiner attributes and patent quality at the USPTO (see Frakes & Wasserman, 2017; Frakes & Wasserman, 2020).

Nevertheless, the major patent offices of the world are wary of the responsibility to consistently issue patents that pass the minimum quality standards; to this end, they have instituted several patent quality improvement mechanisms in the past decade (see Love et al., 2019) such as the Patent Quality Initiative at the USPTO in 2015, Working Party on Patent Quality at the European Patent Office (EPO) in 2017, and Quality Policy on Patent Examination at the Japanese Patent Office (JPO) in 2014. As these reforms are welcome works-in-progress, one could predict that over time, the magnitude of the measurement error in regulatory patent quality would *decrease* rendering the quality assessments *more* precise.

It is noteworthy to make a distinction before I proceed further. The concept of patent value that I study in this paper is different from that of the value of the underlying technology or invention (see Pitkethly, 1997). Bessen (2008) informs that innovators can appropriate value from technology by non-patent means such as lead-time advantage and trade secrets; generally, a patent protects neither all of the inventions nor all of the underlying technological knowledge.

2.3 Review Methodology and Publication-level Analysis

In this section, I first describe the details of the systematic review protocol I employ to identify the papers relevant to the review. Then, for the relevant papers, I analyze the publication trend, study the distribution of the types of papers, and identify the leading authors.

2.3.1 The Protocol for Systematic Review

I follow a transparent and reproducible methodology for searching extant literature, assessing its quality, and synthesizing the content with a high level of objectivity (Kraus et al., 2020). To ensure rigor in my review method, I borrow from the PRISMA standards (Moher, Liberati, Tetzlaff, Altman, & The, 2009; Moher et al., 2015; Page et al., 2021) that recommend preferred reporting items for systematic reviews and meta-analyses originating from medical research; similar standards are more recently introduced in other fields of research (Pullin et al. Pullin, Frampton, Livoreil, & Petrokofsky, 2018). The current review includes the following PRISMA standards that are most relevant to the field of the review: identifying the report as a systematic review, providing an explicit statement of the main objective(s) or question(s) the review addresses, specifying the inclusion and exclusion criteria for the review, specifying the information sources (such as databases) used to identify literature and the date when each was last searched, giving the total number of included studies and summarise relevant characteristics of studies, providing a brief summary of the limitations of the review, and providing a general interpretation of the results and important implications.

I do not restrict the papers by publication date. In this review, I expect to find hundreds of relevant papers from peer-reviewed journals alone (based on van Zeebroeck & van Pottelsberghe de la Potterie, 2011b). I exclude from the review "grey" literature such as working papers and discussion papers because they do not possess a formal review process of any kind. Further, they are works-in-progress papers, some of which do get published later but with substantial changes. Though this exclusion introduces a publication bias in the review, the review outcome remains robust to the exclusion (I check this in unreported studies). The grey literature that I consider in the review includes Ph.D. theses, books, and book chapters. A Ph.D. thesis is of reasonable academic quality as it passes through an institutional supervision by scholars and a rigorous defense process in front of a credible jury prior to acceptance. Book chapters pass through an editorial "review" process (though not at par with academic journals) prior to publication and therefore have a certain level of academic quality associated with them.

Law reviews are edited by law students (Baker, 2008) and are highly relevant in the field of intellectual property; I consider these papers at par with journal articles. As I do not have translation services, I only include papers in English in my study (consistent with Grant, 2007). The review adopts the recommendation by Wanyama, McQuaid et al. (2021) and uses two subject-adequate databases — Web of Science (WoS) and Google Scholar — to retrieve relevant papers. WoS Core Collection is a high-quality collection of peer-reviewed journals, conference proceedings, and books; I use this as the primary database for the review. I use Google Scholar, which is a web-based search engine that catalogs between 2 and 100 million records of academic and grey literature, as the secondary database; this tool is a powerful addition to other traditional search databases used for systematic literature reviews (Haddaway, Collins, Coughlin, & Kirk, 2015).

I conduct the keyword-based search in WoS Core Collection in the 'topic search (TS)' field under the 'advanced search' option using the broad search string: *((quality OR valu*) AND (patent*))*. While the search on WoS was initiated on 26 Jan 2020, the screening and analysis of the results continued until 30 Aug 2020. The search was repeated first on 31 Aug 2020 and then on 1 Dec 2020 and 10 Oct 2021 to identify additional publications during the developmental stages of this research. The initial search yielded 10,883 results whereas the updated searches yielded an additional 1090 results.[2] Among the top 100 journal categories listed for the WoS search results, 58 are chosen (refer to appendix List A1 for the full list) that are related to management, business, economics, finance, sociology, law, engineering, science, and technology. Filtering by these top journal categories yields 6,100 papers for screening in the next stage. An extended search was conducted on 30 Oct 2020 in WoS using an alternative search string *((patent AND (importance OR usefulness OR impact OR influence OR "knowledge flow" OR "knowledge spillover" OR "knowledge diffusion")) NOT (patent AND (valu* OR quality)))* to capture additional papers using terminologies that are alternatives to patent value (or quality).[3] The extended search yielded 9,623 hits, which on database filtering using WoS journal categories reduced to 3,976 papers for further screening. All the search results were updated again using the basic and alternative search strings on 10 Oct 2022; this yielded a set of 1,566 new papers from the basic search string (13,539 papers in all from the basic searches) and 1,345 new papers from the alterative search string (10,968 papers in all from the alternative searches). Overall, database filtering of these two sets of papers resulted in 7,666 and 5,321 papers respectively for the next level of screening.

[2] An alternative search strategy using an identical search string, but in the fields of title or abstract under the 'advanced search' option produces 9,139 results. A check reveals that *all* the results from this alternative search strategy are captured using the first search strategy, making the first search more comprehensive.
[3] These keywords were identified during the detailed analysis of papers identified from the first stage of WoS search.

At the second level of screening, I check each search result from WoS for potential relevance based on its *full text* (because of this requirement, I are not able to qualify papers for the next level of analysis, even if they are potentially relevant based on their abstract if I do not have access to their full text using my institutional account). I qualify a paper for the next level of screening if it provides: (a) *at least one* econometric specification or regression model that includes my attribute of interest – ‘patent value’, ‘patent quality’, or any concept used in the alternative search string discussed above - as an independent or dependent variable; or (b) a theoretical, conceptual, or qualitative study of one or more dimensions of regulatory patent quality.

The qualification condition (a) helps us to efficiently screen several thousands of papers with a vast majority among them having a quantitative research orientation, which is the case with the topic of this review (see van Zeebroeck & van Pottelsberghe de la Potterie, 2011b). To help us screen papers at the second level, I also refer to the typology of patent characteristics from Marco and Miller (2019) to identify patent quality or value indicators. Sorting based on condition (a) results in 621 papers (462 from the basic and 159 from the alternative search strategies) for the next level of screening. I qualify 13 papers based on condition (b) (I label this category as “qualitative papers” in Figure 2.1) and include these papers directly in the final review as they do not require further screening.

In the third level of screening, I include each paper that qualifies condition (a) in the second level of screening in the final review if there is *at least one* relevant econometric specification or regression model that satisfies *each* of the following criteria.

1. The model provides information on the statistical significance levels of the coefficients for the regressors. This is a formal procedure to infer knowledge about a population based on a

statistic gained from a sample (Cowger, 1984). This criterion excludes the ‘machine learning’ models that are termed black-box models, the results of which are notoriously difficult to interpret (see Zhao & Hastie, 2021).

2. The sample for regression consists of “utility” patents as they are known at the USPTO or (invention) patents as they are known in general in most of the other jurisdictions. Other major types of IP rights include design patents and plant patents in the U.S. (USPTO, 2022), utility models and plant breeder’s rights in Japan (Hervouet & Langinier, 2018; JPO, 2022), and utility model patents and design patents in China (see Chen & Zhang, 2019). For these IP rights (except plant patents in the U.S., which are very uncommon), the procedural rules and duration of protection are substantially different compared to those for utility patent rights.

3. The *unit of analysis* is a patent or a patent family (with each patent or family having a *single* observation in the sample). A patent family includes a group of patents filed in multiple jurisdictions for the same invention or a group of related patents filed in a jurisdiction that are linked by priority date(s) (Dechezlepretre, Meniere, & Mohnen, 2017; Martinez, 2011). Based on this criterion, two categories of papers are excluded: (a) papers that investigate the relationship between *firm-level* financial information such as Tobin’s *q*, market value, R&D expenditure, and the like and patent characteristics *aggregated* at the firm level; and (b) papers with the unit of analysis as an aggregate of patents with no information on how the patents in the aggregate are linked.

4. The regression sample is restricted to *granted patents* (also referred to in the literature as registered, issued, approved, successful, or authorized patents) as this criterion is a necessary condition for patent quality and value relationship to hold under the ex-ante theory (Perel,

2014) which grounds this review. When the unit of analysis is a patent family, the rule implies that the family should include at least one granted member.

The multi-level screening of the results from WoS yields 285 papers (166 papers from the basic and 119 papers from the alternative search strategies) for the final review.

I use Google Scholar to identify peer-reviewed journal articles, Ph.D. theses, books, and book chapters. The initial search in Google Scholar was conducted on 10 Nov 2020 using the search string below; the search was repeated on 10 Oct 2022 to update the results:

(regression OR econometric) AND (license* OR royal* OR renew* OR scope OR citation* OR opposition* OR litigat* OR assignment* OR transfer* OR collateral OR family OR trial* OR infringement* OR validity) AND ("patent value" OR "patent quality")*

Compared to WoS, the search on Google Scholar includes additional keywords related to the indicators of patent value or quality that were identified during the analysis of the relevant papers from the WoS search: licensing, renewal, scope, citations, oppositions, litigations, assignments, transfer, collateral, family, infringement, and validity. The search yields about 4,350 results. The unique results from Google Scholar (by discounting those already identified as relevant through WoS) are screened at the first level based on their title or abstract and progressing through the result pages (10 results per web page) until the incidence of relevance per web page reduces significantly (logic adapted from Le, 2019). By the 30th page, the rate of addition of papers to the second level of screening is almost zero; this observation is consistent with the recommendation of Haddaway et al. (2015). The first level of screening from Google Scholar results in 190 papers (155 from the first search and 35 from the repeat search).

At each level of screening in Google Scholar, each journal article is subject to the same inclusion criteria as that for WoS; I also use an additional criterion that the corresponding journal must be currently indexed in WoS. This additional criterion helps in identifying relevant journal articles that are not capturable through the search strategies employed in WoS. The screening of the results from Google Scholar yields 27 unique papers for the final review. Finally, snowballing (search for references of relevant references, Greenhalgh & Peacock, 2005) and subjecting the resulting papers to the same screening criteria used for those from WoS and Google Scholar adds 15 papers to the final review (340 papers in all). The flow diagram in Figure 2.1 illustrates the number of papers identified through the different stages of the screening process.

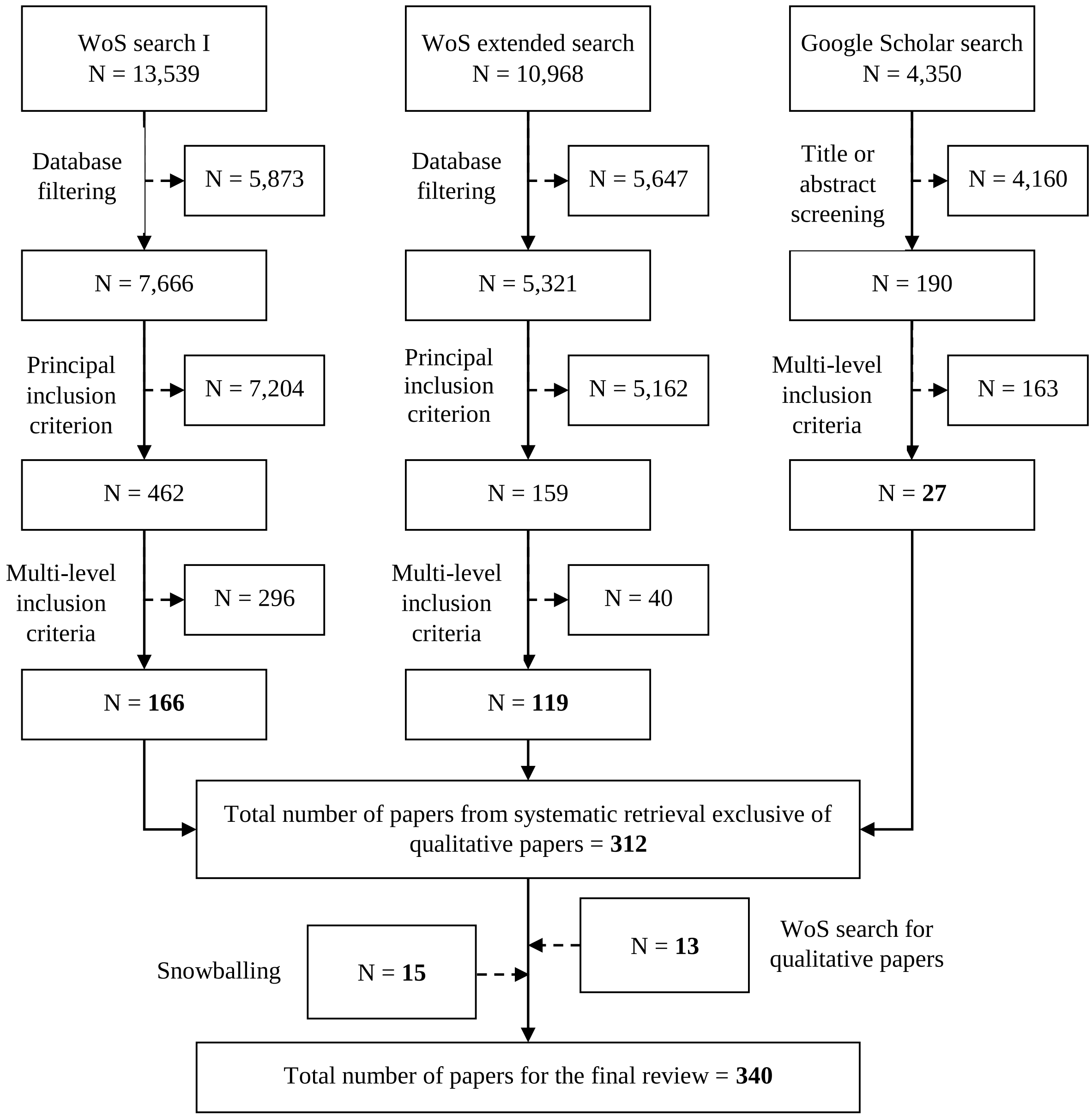

Figure 2.1. Flow Diagram of the Screening Steps in the Systematic Literature Review. The Figures in Boxes Correspond to the Number of Papers.

2.3.2 Publication-level Analysis

The publication trend for the 340 papers is presented in Figure 2.2 The publication year spans from 1974 to 2022 (since I conduct the last search on 10 Oct 2022, the publication count for 2022 is right-truncated and the size of the interval for 2019-2022 is only four years compared to five years for other intervals).

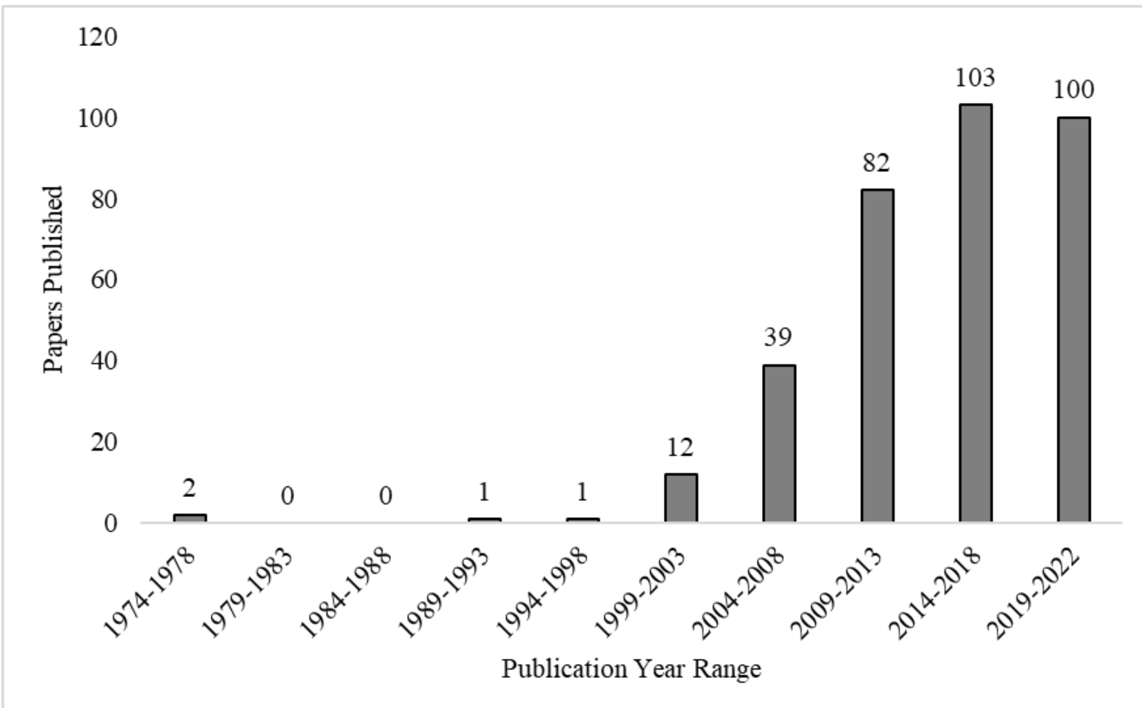

Figure 2.2. Publication Trend of 340 Papers in the Review

Looking at Figure 2.2, overall, the trend is flat from 1974 until 2002 after when there is a sharp and visible uptick that continues to rise resembling the early exponential phase of sigmoidal curves. This observation concurs with the general understanding among scholars of a burgeoning academic interest in patents. Several reasons can be attributed to this growth such as the relative ease of availability of patent data, explosive patenting in the 21st century, the significance of patents to society and practice, and the multi-disciplinary nature of patents as information sources.

The earliest article in the field is by Sears (1974) who laments the inadequate application of the patentability standard of obviousness at the USPTO resulting in poor quality patents. Silverstein (1974) provides a comparative discussion of the patentability standards in the United States with those abroad. An early seminal paper by Trajtenberg (1990) establishes the importance of citing patents (commonly known as “forward” citations) as indicators of patent value.

The distribution of papers by publication type is presented in Table 2.1. Between the peer-reviewed and grey literature categories, the former accounts for a majority share of 334 papers (98.2 percent). Among the peer-reviewed publications, journal articles have a maximum share of 97.3 percent (325 papers), whereas conference proceedings and conference papers have a combined share of 2.7 percent (9 papers). Among the grey literature articles (6 papers), three are Ph.D. theses and an equal number are book chapters. Among the peer-reviewed publications, the top six journals by count are Research Policy (66 papers), Scientometrics (21 papers), Strategic Management Journal (13 papers), Management Science (12 papers), Industrial and Corporate Change (10 papers), and Journal of Technology Transfer (10 papers).

Table 2.1. Distribution of Literature Type and Paper Type in the Review

Literature type	**Paper type**	**Papers**	**Share of total (percent)**	**Marginal share (percent)**
Peer-reviewed		**334**	98.2	100
	Journal article and law review	325		97.3
	Conference paper and proceeding	9		2.7
Grey		**6**	1.8	100
	Ph.D. thesis	3		50
	Book chapter	3		50
Total		**340**	100	

Next, looking at the distribution of authors (irrespective of their order of authorship in the papers with co-authors), Antonio Messeni Petruzzelli has the highest count of 10 papers, followed by Dietmar Harhoff with nine papers, each of Alan Marco and Federico Caviggioli with five papers, and each of Alfonso Gambardella, Deepak Hegde, Henry Delcamp, Sam Arts, Sean Seymore, and Yong-Gil Lee with four papers. These scholars are the most frequent contributors to the subject of this review.

2.3.3 Patent Quality and Value Indicators

First, I present the temporal partitioning scheme for the distribution of patent characteristics uniquely into those associated with patent quality or value. In the following sections, I discuss the different types of patent quality and patent value indicators respectively.

2.3.3.1 Temporal Partitioning of Patent Characteristics

To establish *internal validity* between variables x and y, a necessary (but not sufficient) condition is the temporal precedence of x over y (see Calder, Phillips, & Tybout, 1982). The information gleaned from the analysis of 340 relevant papers in this review yields a text corpus of patent characteristics used as regressors or response variables (regressands) based on idiosyncratic considerations of “patent value” or “patent quality”. The first step in the synthesis of this information involves partitioning the patent characteristics along the temporal dimension *exclusively* into those associated with patent quality or patent value; based on the ex-ante theory, the event of the patent grant is the cut-off point that allows for this partitioning. Marco and Miller (2019) provide a taxonomy of patent characteristics that includes *application characteristics* that are observable at the time of filing a patent application, *examination characteristics* that capture the details of the examination of a patent application, *patent (grant) characteristics* that are associated with the grant of a patent, and *post-grant characteristics* that are observable after a patent's grant. The first three types of patent characteristics along the patent timeline can be clubbed into a bigger group - *pre-grant characteristics.* This temporal partitioning results in the first level of organization of patent characteristics into those associated with patent quality (pre-grant characteristics) and patent value (post-grant characteristics). The time-measuring patent characteristics such as filing year, priority year, or grant year of patent, and age of patent, which are typically measured as the duration between the priority date, filing date, or grant date of a patent and a later, study-defined cut-off date in the post-grant life of a patent (Sapsalis, van Pottelsberghe de la Potterie, & Navon, 2006), are excluded from this partitioning as these variables are, by design, used as controls in patent quality or patent value regressions (e.g., see Popp, 2006) to account for possible structural changes in patent quality or value over time.

2.3.3.2 Types of Pre-Grant Patent Characteristics as Patent Quality Indicators

A patent document is a source of technology, business, and legal aspects (Danish, Ranjan, & Sharma, 2019). The application characteristics of a patent (discussed earlier) can be further classified into six subtypes based on the nature of business or technical information they provide: (1) *filing strategy* of a patent that informs on the decision made by an applicant to opt for national filing vis-a-vis an international patent filing or choose the countries for protecting the claimed invention; the filing strategy may signal the market potential or the stage of maturity of the underlying invention (see van Zeebroeck & van Pottelsberghe de la Potterie, 2011a); (2) *application claims* that informs on the semantics (meaning of words) (see Cotropia, 2005), category (subject matter) (Reitzig, 2004a), structure (layout of dependent and independent claims) (Marco et al., 2019), or length (wordiness) of claims of a patent application (Marco et al., 2019);

(3) *disclosed content* that provides details of the claimed invention that's made public in the patent specification (the descriptive sections of a patent) to disseminate the codified knowledge among a wider audience (Seymore, 2010); (4) *applicant cited literature* (commonly known as "backward" citations) that captures information on the technologically related patents (Harhoff & Reitzig, 2004) as well as scientific literature (Carpenter, Cooper, & Narin, 1980) (also known as "non-patent literature") based on the citations to these made by the applicant; (5) *team composition* that conveys information about the team size or nationality of the inventors (for e.g., see Sapsalis et al., 2006; Singh & Fleming, 2010); and (6) *ownership* that informs on whether a patent application has singular or joint ownership, and when jointly owned, the nature of the entities in the ownership (Sonmez, 2018). The patent application characteristics are appealing to a researcher studying patent quality or value as these are available in a patent document at time-zero – the date a patent application is first published (Reitzig, 2004a). The various measures corresponding to the different types of patent application characteristics are provided in Appendix List A2.

The examination-cum-grant characteristics of a patent can be grouped into four subtypes based on the nature of the technical or legal information they provide such as (1) *prosecution history* that reflects the nature of the transaction between the applicant and the examiner until a patent's grant (Marco & Miller, 2019); (2) *granted claims* that captures the semantics (meaning of words), category (subject matter), structure (layout of dependent and independent claims), or length (wordiness) of claims of a patent at grant; (3) *external cited literature* that captures information on the technologically related patents or scientific literature based on the citations to these made by an examiner (Hegde & Sampat, 2009) or a third party (Kapoor, Karvonen, Mohan, & Kassi, 2016);

and (4) *technology scope* that provides information on the assignment of a patent into one or more standardized technology classes by an examiner (Lerner, 1994).[4]

The distribution of papers studying the application, examination, and grant characteristics is presented in Table A1 in the appendix. Refer to Table A4 in the appendix for identifying the papers corresponding to the codes in Table A1 (and other such tables with codes). The various measures corresponding to the different types of patent application characteristics and patent examination-cum-grant characteristics are provided in List A2 and List A3 in the appendix respectively. Among the subtypes of patent application characteristics, the *applicant cited literature* is the most studied (198 papers); *team composition* is the second most studied (152 papers), followed by *filing strategy* (123 papers), *ownership* (101 papers), and *disclosed content* (10 papers). The *application claims* patent characteristic is the least studied (nine papers).

Among the examination-cum-grant characteristics, *technology scope* is the most studied (198 papers) followed by *granted claims* (182 papers) and *prosecution history* (82 papers); *external cited literature* is the least studied with 18 papers.[5] Many papers in this review use "derived" (or composite) measures as regression variables. These measures are obtained from custom combinations of two or more items of the same or different kind in the pre-grant and/or post-grant patent characteristic groups and tend to average out different patent quality measures (see Higham et al., 2021). Because of the heterogeneity of such measures, they do not fit into the synthesis

[4] The International Patent Classification (IPC) codes are used universally in patents and are the basis for the creation of two other classification systems - the Cooperative Patent Classification (CPC) system jointly adopted by the EPO and USPTO, and the FI system of the JPO. See details here: https://www.wipo.int/classifications/ipc/en/faq/ and here: https://www.jpo.go.jp/e/system/patent/gaiyo/seido-bunrui/index.html

[5] If a paper does not make a distinction between *applicant cited literature* and *external cited literature* explicit, we consider the type of backward citation under the former category. This inclusion is likely to bias the distribution of these patent characteristic subtypes in Table A1.

scheme of this review. Refer to a recent review (Grimaldi & Cricelli, 2020) for more information on such measures.

2.3.3.3 Types of Post-Grant Patent Characteristics as Patent Value Indicators

Perel (2014) studies patent value in the context of patent licensing fees. The measures of patent value can be broadly classified into three types based on the precision of the method of measurement as *direct measures*, *estimates*, *and indicators* (Giummo, 2010). The *direct measures* of patent value include the monetary value of patents observed during patent-based transactions (Kramer, 2007) such as patent auctions, patent infringement awards, and patent licensing deals. The *estimates* of patent value are indirect measures such as the economic value of patents obtained from surveys of inventors or patent owners (Harhoff, Scherer, & Vopel, 2003), renewal model of patent value (Schankerman & Pakes, 1986), abnormal stock market returns to a firm around the grant date of a patent (Kogan et al., 2017), sales of products protected by patents (Guo, Hu, Zheng, & Wang, 2013), and returns to patented inventions based on inventors' compensation records (Giummo, 2010; Giummo, 2014). A characteristic feature of patent value is that it has a skewed distribution with a very long tail into the high-value side (see for e.g., Scherer, 1965); because of this feature, estimates of patent value, for example, based on renewals, do not directly reflect the value of patents in the "upper tail" of the distribution (Bessen, 2008).

The indicators of patent value are the post-grant patent characteristics; these indicators can be classified into five subtypes based on the nature of their impact such as: (1) *legal impact* that includes litigation of a patent (Lerner, 1994), reissue of a patent, post-grant opposition or validity challenge of a patent at a patent office (Harhoff & Reitzig, 2004); (2) *economic impact* that includes licensing (Gambardella, Giuri, & Luzzi, 2007) or reassignment (Serrano, 2010) of a patent, commercialization of a patent (Chandy, Hopstaken, Narasimhan, & Prabhu, 2006), pledging of a patent as a collateral for securing funds (Fischer & Ringler, 2014), renewal of a patent (Bessen, 2008), or sale of a patent in an auction (Fischer & Leidinger, 2014); (3) *technological impact* that includes the conferral of a prestigious award to a patented invention (Arts, Hou, & Gomez, 2021) or the inclusion of a patent as an essential patent to comply with a technical standard (Kramer, 2007); (4) *knowledge internalization* that includes *self-citing patents* — citations from patents having the same assignee as the focal patent — which are indicative of the research investments made by the focal assignee to build a proprietary technology base (Hall, Jaffe, & Trajtenberg, 2005); and (5) *knowledge diffusion* that includes *external citing patents* — citations by a third party such as a non-focal assignee or a patent examiner (see Alcácer, Gittelman, & Sampat, 2009; Criscuolo & Verspagen, 2008) — which are proxies for spillover of the knowledge embodied in the focal patent among the public (see Jaffe, Trajtenberg, & Fogarty, 2000).

The distribution of papers studying the different attributes of patent value is presented in Table A2 in the appendix. The various measures corresponding to the different types of post-grant patent characteristics in Table A2 are provided in List A4 in the appendix. The direct measures of patent value are the least studied (nine papers). The infrequent usage of this precise and reliable measure of patent value is due to the rarity of events that provide such measures (Schankerman & Pakes, 1986). Rather, the value of a patent is mostly inferred based on certain indicators. The indicators corresponding to *knowledge diffusion* are the most studied by 218 papers followed by *knowledge* *internalization* (201 papers), *economic impact* (116 papers), legal impact (65 papers), and *technological impact* (11 papers).[6]

2.4 Dimensions of Patent Quality and a Conceptual Model of Patent Value

Here, I first present the different dimensions of patent quality and patent value. Then, I map the different types of patent quality and value indicators discussed in the preceding section onto the different (corresponding) dimensions of patent quality and value. Finally, I advance a conceptual model of patent value.

2.4.1 Dimensions of Patent Quality and Patent Value

In the next step, the different types of pre-grant and post-grant patent characteristics are mapped onto the appropriate dimensions of patent quality and value. I delineate the dimensions of patent quality and patent value in this section and do the mapping in the next section. Patent quality is a multidimensional concept (Higham et al., 2021). The emergent ex-ante theory proposes four dimensions for patent quality: *subject matter eligibility, utility, novelty and non-obviousness, and clarity and definiteness*. The variable conceptualizations of the ex-ante theory are centered around the patentability standards of the USPTO. The more fully a generalization satisfies the criteria of a theory, the more it deserves the label theory (Weick, 1989). To understand the dimensions of patent quality from a broader perspective, a comparative analysis of the requirements for patentability in the three *major* patent offices of the world known as the 'triad' (Frietsch & Schmoch, 2010) - the USPTO, EPO, and JPO – should serve as a reliable starting point; this

[6] If a paper does not make a distinction between self-citing and external-citing patents, we consider the type of forward citation under both the categories of *knowledge internalization* and *knowledge diffusion*. This scheme is likely to bias the distribution of these post-grant patent characteristic subtypes in Table A2.

comparison is succinctly presented in Table 2. It should be noted that the definitions in Table 2 are excerpts taken from the legal statutes to facilitate a reasonably accurate comparative analysis without getting deep into the complicated legal connotations of terms. It is apparent from Table 2 that three of the patentability requirements of novelty, non-obviousness (or inventive step), and utility are common among the triadic patent offices; Martinez and Guellec (2004) inform that though the definitions for these three standards differ only slightly, their interpretability and application by the patent examining authorities may vary to a greater extent. My objective is to conceptualize patent quality broadly so that it is usable in empirical investigations of patent quality in any jurisdiction. I do this by finding a common theme for each patentability standard across the triadic patent offices.

From Table 2.2, the novelty standard, in general, seeks to determine whether a claimed invention is new public knowledge or not. Thus, for all granted patents, the concept of novelty as a variable reduces to a *constant*, rendering this aspect of patent quality redundant for empirical analyses. In discussing the ex-ante theory, Perel (2014) proposes ‘novelty and non-obviousness’ as an integrated aspect of patent quality; my analysis excludes novelty from patent quality measurements under the ex-ante lens.

Table 2.2 Patentability Standards at the Triadic Patent Offices USPTO, EPO, and JPO

Standard	Patent office	Definition of the standard
Subject matter eligibility (SME)	USPTO	The patent is directed to a process, machine, manufacture, or composition of matter, or any new and useful improvement thereof; exclusions are determined by the law on case-to-case basis (35 USC 101 USPTO, 2020a)
SME	EPO	The claims shall define the matter for which protection is sought. The EPC refers to different "categories" of claim ("products, process, apparatus or use"). (EPC Article 52, 84 EPO, 2021)
SME	JPO*	There are two basic kinds of claims – physical entity (product, apparatus, system, etc) and activity (method, process, use, etc) (see requirement for claims, JPO, 2017)
Utility	USPTO	A claimed invention must be useful or have a utility that is specific, substantial, and credible (35 USC 101, USPTO, 2020a).
Utility	EPO	The patent can be made or used in any kind of industry, including agriculture (EPC Article 57 EPO, 2021)
Utility	JPO*	The invention for which the patent is sought has industrial applicability vide Article 29 (1) of JPO (2021)
Novelty	USPTO	The patent, prior to its effective filing date, was not patented or described in any printed publication, or in public use, on sale, or otherwise available to the public (35 USC 102 USPTO, 2020a)
Novelty	EPO	The patent does not form part of the state of the art that comprises everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing of the European patent application (EPC Article 54 EPO, 2021)
Novelty	JPO*	The invention for which a patent is sought is not public knowledge, publicly known to be worked, described in a distributed publication, or made available for public use over telecommunications lines within Japan or in a foreign country before the filing of the patent application under Article 29 (1) of JPO (2021).
Non-obviousness	USPTO	The difference between the patent and the prior art is such that the patent would not have been obvious before its effective filing date to a person having ordinary skill in the art to which the patent pertains (35 USC 103 USPTO, 2020a)
Inventive step	EPO	The patent is not obvious to a person skilled in the art with respect to the state of the art (EPC Article 56 EPO, 2021)
Inventive step	JPO*	A person may not obtain a patent if before the filing of patent application, a person of ordinary skill in the art of the invention would have easily been able to make that invention vide Article 29 (2) of JPO (2021).
Disclosure	USPTO	The patent's specification contains a written description of the invention, and the manner and process of making and using the invention in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and the best mode contemplated by the inventor of carrying out the invention (35 USC 112 USPTO, 2020a)
Disclosure	EPO	The patent discloses the invention in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art (EPC Article 83 EPO, 2021)
Disclosure	JPO*	The description must contain a detailed explanation of the invention that is clear and sufficient to enable a person ordinarily skilled in the art of the invention to work the invention vide Article 36 (1) of JPO (2021)

* The rules are excerpts taken from the Japanese law translation in English of the Japanese Patent Act provided by the JPO.

The statutory requirement of non-obviousness (or equivalently, inventive step) calls into question a person having “ordinary skill in the art” as per the USPTO or JPO, or “skill in the art” as per the EPO. This definitional element makes this quality attribute markedly different and perhaps more difficult to measure compared to the other patentability standards. This variable though dichotomous, also has an additional relevant attribute to consider. That is, for a granted patent, a relevant obviousness inquiry would be: *how much* different is the claimed invention from the prior art (Barton, 2003; Eisenberg, 2004; Sears, 1974)? Therefore, the *non-obviousness or inventive step* of a patent as the first dimension of patent quality can be defined as *the extent of advancement of a patented invention over prior public knowledge*. It should be noted that all the definitions explicated herein are developmental in the field of the review and remain at the disposal of scholarship for further refinements.

I adapt the definition of Perel (2014) for *utility* of a patent as *the extent of the specific and practical usefulness of a patented invention*. This definition reflects the examination guidelines for the utility requirement at the USPTO (under section 2107 of Manual of Patent Examining Procedure) (USPTO, 2020a). The aspects of specificity and practicality in the definition also broadly capture the essence of the ‘industrial application’ of inventions (see Machin, 1999) for the utility standard as per the EPO and JPO.

As apparent from Table 2.2, the requirement of subject matter eligibility differs significantly among the triadic patent offices, particularly considering what is *excluded* from this doctrine (for a detailed discussion, see van Pottelsberghe de la Potterie, 2011). The presumption of validity rule would imply that a granted patent has eligible subject matter; understanding *what* this subject matter is would be important to measure this dimension of patent quality. Perel (2014) does not specify subject matter as a patent quality attribute. Based on the common theme in the definitions for subject matter in the triadic patent offices, I define *subject matter,* which is the third dimension of patent quality, as *the categories of claims of a patented invention*. Evidently, the measure for subject matter would have the lowest variability compared to that for any other dimension as the categories of claims allowed in the triadic patent offices are limited, with the most common ones being process, product (or composition of matter), system, and method of use.

Finally, turning attention to the disclosure standard, it is apparent from Table 2.2 that the USPTO differs from the other triadic offices in having the "best mode" requirement (also see Martínez & Guellec, 2004), whereas a substantial commonality among the offices is whether the disclosure of a patent would *enable* a skilled artisan to practice the claimed invention. After the U.S. transitioned to the 'first-to-file' patent system in 2011 as a part of its objective to harmonize its patent obligations with the other major patent offices of the world, the patent statute has made an exception to the disclosure requirement that failure to disclose the best mode shall *not* be a basis for invalidity of claims (Braga, Ribeiro de Souza, Leal de Lima Soares, & Rodrigues, 2018); this concession essentially makes enablement the *core* element of the disclosure standard across the triadic patent offices. As per Holbrook (2006), the enablement doctrine implies that (among other things) once the patent term expires, the public will be able to practice the invention freely, strictly based on the patent disclosure; more importantly, the disclosure requirement implements the *quid pro quo* canon of the patent system wherein an inventor receives exclusionary rights in exchange for the public disclosure of the claimed invention. In comparing the definitions for the disclosure standard in Table 2, I define the *sufficiency of disclosure* as the fourth dimension of patent quality as *the extent of clarity and completeness with which a patented invention is described in a patent specification that would enable a person skilled in the art to practice the invention*. While Perel

(2014) names this aspect of patent quality as ‘clarity and definiteness’, I adopt the naming convention of the patent offices to appreciate its importance *prima facie* from a public perspective.

I present the list of 13 papers that discuss one or more dimensions of regulatory patent quality in Table A3 in the appendix. Six papers discuss *sufficiency of disclosure*, five discuss *non-obviousness or inventive step*, and four papers each discuss the *utility* and *subject matter* aspects of patent quality.

Patent value, in line with the two-fold objective of the patent system of incentivizing innovation for the benefit of the patentee and facilitating knowledge diffusion for the public good, has two discernible dimensions of *private value* which is *the measure of the financial returns from a patented invention to the patent holder* (Ribeiro & Shapira, 2020) and *social (or public) value* which is *the measure of the contribution of a patented invention to social welfare* (Baron & Delcamp, 2012). Perel (2014) does not differentiate between the two aspects of patent value.

2.4.2 Mapping Patent Quality and Value Indicators onto Corresponding Dimensions

Perel (2014) suggests an open list of patent quality indicators. The different types of pre-grant patent characteristics and patent quality indicators discussed in the earlier section provide a good frame of reference to map these characteristics onto the appropriate dimensions of patent quality. Whereas the patent application characteristics provide information about the technical and business aspects of a patent, the examination-cum-grant characteristics capture the technical and legal aspects. The patent quality indicator subtypes of *filing strategy, team composition*, *ownership,* and *technology scope* are arguably associated with the industrial usability of the claimed invention; these could be considered indicators of the *utility* dimension of patent quality.

Both *application claims* and *granted claims* of a patent have at least four features of semantics, category, structure, and length. For both *application claims* and *granted claims*, structure is the most explored feature (see List A2 and A3 in the appendix for the different measures), whereas length is a more recently explicated measure of patent “scope” (Marco et al., 2019). Both the semantic and category features are relatively understudied (evidently based on the elements in List A2 and A3). Logically, I consider the attribute of *category* for both *application claims* and *granted claims* under the *subject matter* dimension of patent quality. I map the remaining features of both *application claims* and *granted claims* onto the *utility* dimension of patent quality as claims reflect the strength of exclusionary rights of patents (see Cotropia, 2005), and since they are (differentially) priced by the patent office (see Harhoff, 2016), their inclusion in a patent has a straightforward association with the potential benefits of the patent. The choice of indicators for *non-obviousness or inventive step* is relatively straightforward. Evaluation of the body of knowledge that qualifies as the prior-art for a claimed invention is critical to ensure that an issued patent is non-obvious (Cotropia, Lemley, & Sampat, 2013). Therefore, the application characteristic of *applicant-cited literature* together with the examination characteristic of *external cited literature* can be considered as indicators of the *non-obviousness or inventive step* dimension of patent quality. The patent quality indicator of *disclosed content* is a logical assignment as an indicator of the *sufficiency of disclosure* dimension of patent quality.

Finally, the patent characteristics included under the *prosecution history* subtype reflect the intensity of examination of a patent application, which Marco and Miller (2019) label as “patent examination quality”. The events and interactions during the examination of a patent application reflect the intentions of the applicant in getting a patent issued and hence are likely to convey meaningful signals about the quality of the patent. Several studies suggest this link. Investigating a large sample of patents at the EPO, Harhoff and Wagner (2009) find strong evidence that applicants expedite grant proceedings for their most "valuable" patents through requests for accelerated examination. Harhoff and Reitzig (2004) posit that the duration of interaction between patent applicants and examiners is driven by the inherent "complexity" of the invention. Regibeau and Rockett (2010) suggest that more "important" patents are pushed through the patent approval process more eagerly by applicants. Marco and Miller (2019) posit that a plausible reason behind applicants filing a request for continued examination (US patents) is the high "perceived value" of these inventions. As the examination-cum-grant patent characteristic subtype of *prosecution history* can be linked to patent quality in general, I consider these characteristics as indicators of each of the dimensions of patent quality.

The organization of the patent application, examination, and grant characteristic subtypes into the different categories of indicators of patent quality and the mapping of the indicators onto the corresponding patent quality dimensions is shown in Figure 2.3. Consistent with literature and based on the nature of the information that the different subtypes of post-grant patent characteristics contain, I map *legal impact*, *economic impact*, *technological impact*, and *knowledge internalization* onto the *private value* dimension and *knowledge diffusion* onto the *social value* dimension of a patent. The mapping of the different indicators of patent value onto the corresponding patent value dimensions is shown in Figure 2.4. The organizational maps shown in Figures 2.3 and 2.4 are pictorial representations of the outcome of the synthesis of the content from the 340 papers identified in this review.

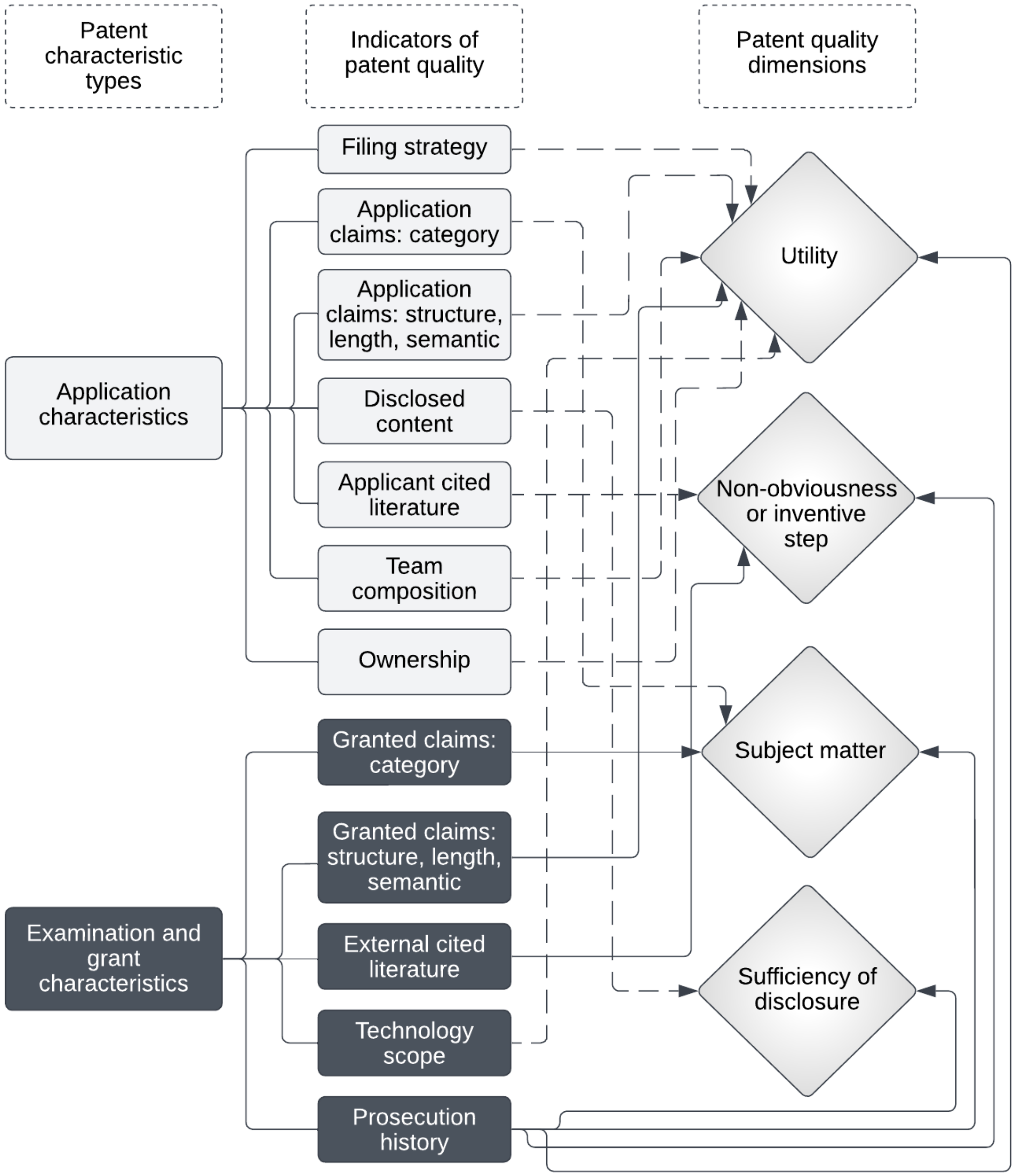

Figure 2.3. An Organizational Map of Pre-Grant Patent Characteristic Types, Indicators of Patent Quality, and Patent Quality Dimensions

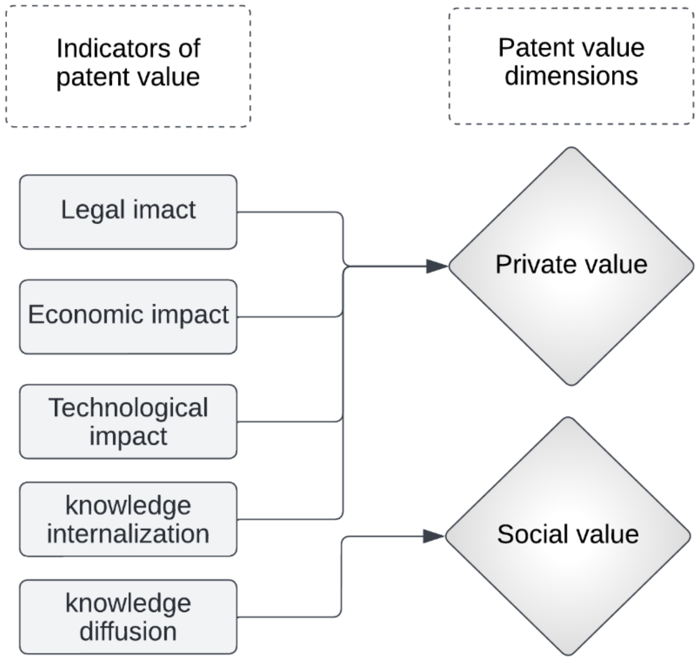

Figure 2.4. An Organizational Map of Indicators and Dimensions of Patent Value

2.4.3 Towards a Conceptual Model of Patent Quality and Value

A conceptual model depicting the relationship between the different dimensions of patent quality and those of patent value is shown in Figure 2.5. This review identifies several studies that use assignee-level characteristics as independent variables in patent value regressions. The inclusion of such variables is based on the rationale that patent value depends on the synergies of all the managerial functions of an assignee (Hsu, Lee, Tambe, & Hsu, 2020). Wagner (2009) argues that patent value depends not only on the quality of a patent but also on other factors. An organized typology of such assignee-level characteristics is beyond the scope of this review; for interested readers, refer to a recent working paper by Hsu, Lee et al. (2020). Further, this review identifies a category of factors that influence patent value — the context in which patent value is studied.

Representative examples of contextual variables include information about inventors (not obtainable from patent documents), competitors, markets, litigating courts, patent offices, and the like. Accordingly, I include these contextual variables as a factor of patent value. Finally, as I discuss earlier, I include time-based controls as another factor of patent value in the conceptual model.

It is noteworthy that the private and social value concepts of a patent are not discordant in nature. The exclusive right from holding a patent has the potential to provide *positive* economic returns to the innovator whereas the knowledge diffusion from the disclosure of the invention in the patent has the potential to *benefit* the society at large. Arguably, since both the parties (the innovator and the society) stand to benefit from patents, *theoretically*, each of the different dimensions of patent quality explicated in our conceptual model has a positive relationship with the private and social value of patents.

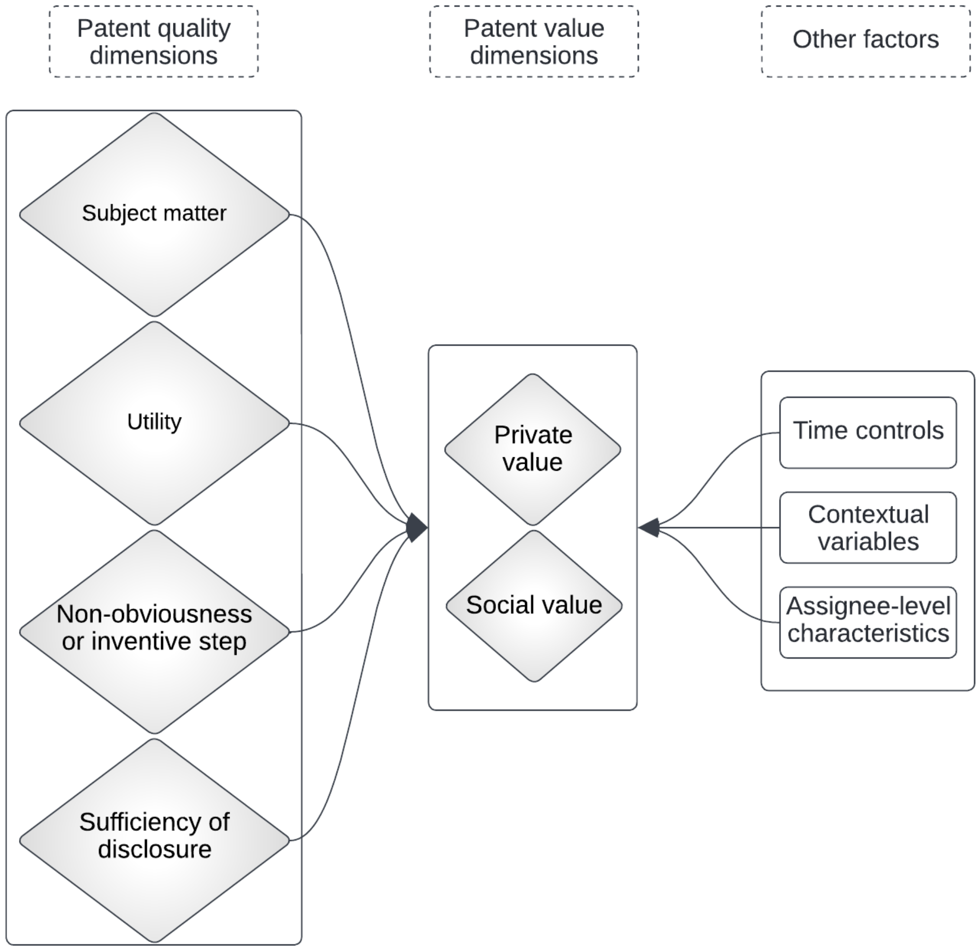

Figure 2.5. Conceptual Model Showing the Relationship Between the Different Dimensions of Patent Quality and Patent Value

2.5 Endogeneity, Validity, and Future Research Agenda

Hamilton and Nickerson (2003) inform that in the field of strategy, management's decisions are endogenous to their expected performance outcomes. Endogeneity occurs when a dependent variable depends on some unmodeled factors that also drive the independent variable (Antonakis, Bendahan, Jacquart, & Lalive, 2014). Endogeneity is a concern in my conceptual model. Reitzig

(2004) posits that though patent quality indicators are attractive in patent valuation, their disadvantage lies in their endogeneity because the patent is drafted by the proprietor who can "infer on" the value of the patent. Bessen (2008) argues that innovators can exert varying degrees of effort in the examination and enforcement of their patents. For instance, for a patent application with high potential value, innovators can invest more effort in obtaining more claims or broadening the scope of the claims which would make the patent more resistant to invalidation challenges. They can also include more citations to immunize the patent against possible prior art during litigation. Innovators can also obtain more patents on related technologies to reduce the future threat from competitors. Galasso and Schankerman (2014) inform that technologies with greater commercial potential are both more likely to be protected by patents (with strong rights) and these patents are more likely to be attractive targets for follow-on innovation.

Since patent quality and value are temporally related in my conceptual model, one necessary condition for *internal validity* (see Calder et al., 1982) of the model is inherently satisfied. In empirical investigations, the other necessary condition of causality is extremely difficult to establish because of endogeneity in my model. Shadish and Cook (2002) inform that though randomized experiments such as those used in medical research are the gold standards to test causality, they may be undesirable for some researchers (for example, in management) for practical or ethical reasons; the authors also inform that prudent use of quasi-experimental designs, which do not qualify the "true" random assignment criterion but provide means to conduct experiments, are valuable to a researcher in testing causal hypotheses. Representative papers in my review that use quasi-experimental research designs are Marco and Miller (2019) (propensity score matching), Galasso and Schankerman (2014) (instrumental variable), Martinez-Ruiz and Aluja-Banet (2009) (structural equation modeling), and Baruffaldi and Simeth (2020) (regression discontinuity design). To understand the principles behind these econometric methods, refer to seminal expositions by Angrist, Imbens, et al. (1996), Angrist and Pischke (2009), Rosenbaum and Rubin (1983), Imbens and Lemieux (2008), and Anderson and Gerbing (1988). Future studies using quasi-experimental designs to test my conceptual model would make significant contributions to policy and practice.

Construct validity generally refers to the vertical correspondence between an unobservable construct and its purported measure (Peter, 1981). *Nomological validity* is the extent to which the relationship between constructs is supported by hypotheses drawn from the underlying theory (O'Leary-Kelly & J. Vokurka, 1998; Peter, 1981). The current review informs on a myriad variety of measures and indicators for patent quality or value to choose from in future empirical inquiries related to our work. For example, if one has to study the dimensions of regulatory patent quality, the outcome of a factor analysis would contribute to the construct validity of the conceptual model (see Peter, 1981). One can also test my conceptual model based on several hypotheses, the outcome of which would help to establish the model's nomological validity; ultimately, a study's research question(s) or design, the researcher's accessibility to data, and the method of analysis would determine the outcome of the study. Future methodological papers might introduce more precise measures of patent quality or value to the current body of knowledge. Essentially, empirical studies that test the construct and nomological validities of my conceptual model in the future might refine, validate, reorganize, or advance the core ideas (concepts, dimensions, indicators, and measures) that underpin my conceptual model.

For a theory, Calder, Phillips et al. (1982) inform, *external validity* examines whether or not an observed causal relationship should be generalized to and across different measures, samples, contexts, and times. Since external validity is contingent on causality, the problems with the latter also affect the former. Nevertheless, for an empirical researcher, the “applicability” of my conceptual model across different settings can be assessed to an extent by a *meta-analysis*, which Glass (1976) defines as the statistical analysis of a large collection of analysis results from individual studies to integrate the findings. In their critical review of patent value determinants, van Zeebroeck and van Pottelsberghe de la Potterie (2011b) do a similar analysis under the heading of “consistency” study. Meta-analysis of the studies that study the relationship between patent quality and value is a worthy research avenue in the future.

Although artificial intelligence (AI) and machine learning (ML) techniques have been used in the past to study patent quality or value, these studies are not a part of this review as the models in these papers do not have the explainable power (for e.g., see Goebel et al., 2018) of traditional econometric or regression models. Nevertheless, I expect that explainable AI and ML models in the future can identify latent dimensions of patent quality. Accordingly, my conceptual model remains amenable to future refinements and elaborations.

The dimensions of patent quality that I explicate may change over time due to macroeconomic factors. Firstly, national, regional, or international policies or agreements in the future might change the patentability requirements, which might necessitate re-conceptualization(s) of regulatory patent quality or its dimensions which I advance in this review. To provide a context, Mahne (2012) informs that European countries have been striving to create a Unitary Patent which would be valid in all these countries upon issuance and a Unified Patent Court which would have nearly EU-wide jurisdiction over European and Unitary Patents. As per the current EPO notification (see EPO, 2022), Unitary Patents will operate on the rules of the EPC and will have the same standards of examination as European patents. The proposed Unified Patent Court is likely to have a significant impact on the opposition and litigation proceedings for Unitary Patents.

Though my broad conceptualizations of patent quality and its dimensions seem to be consistent with what would become the standards of patentability for a Unitary Patent, I expect that future legislation like this might affect my specifications of patent quality.

2.6 Conclusions

Patent value is a subject of burgeoning empirical research. However, the extant literature on patent value and patent quality does not differentiate between these concepts. Drawing upon the emergent ex-ante theory of patent value (Perel, 2014) that proposes a positive and direct relationship between patent quality and value, this systematic literature review provides a synthesis of the content from 340 papers that study patent value or quality from multiple research fields. The review presents a comprehensive organization of the different types of patent quality and value indicators, conceptualizes patent quality from a regulatory perspective based on the standards of patentability adopted by the triadic patent offices, delineates the dimensions of patent quality and value, and maps the patent quality and value indicators onto the corresponding patent quality and value dimensions. The review finally advances a conceptual model linking patent quality and value.

The current review advances the emergent ex-ante theory based on the research approach of systematic review and synthesis of extant literature. An enterprising researcher might adopt an interpretive research philosophy and investigate the concepts and dimensions underlying the ex-ante theory and the relationship between them in a social setting. This qualitative research approach could reinforce my findings or may even elaborate my conceptual model further. My efforts undeniably provide an anchor for future studies in this direction.

My study has a limitation. Though I conduct a rigorous systematic review of a burgeoning topic of research, to screen the several thousands of papers that result from a combination of multiple search strategies, I use proper quality controls to ensure that I correctly include and analyze most of the relevant papers. Though I have taken adequate precautions to minimize bias in my methodology, due to the sheer volume of work, I could have inadvertently excluded some relevant papers. To this extent, an unavoidable error creeps into my review. Notwithstanding, I have a very high level of confidence in my findings that my results would be robust to such exclusions. Of course, I take ownership of all the errors.

Finally, I am profoundly thankful to the three anonymous reviewers for their remarkable patience in thoroughly reading the prior versions of this manuscript and their constructive suggestions. I realize that working on the corrections has improved the quality of this paper by several notches.

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Appendix A

List A1

Journal categories used for filtering of search results in WoS

Management, Engineering Civil, Economics, Computer Science Theory Methods, Chemistry Physical, Business, Optics, Automation Control Systems, Regional Urban Planning, Engineering Multidisciplinary, Environmental Studies, Engineering Electrical Electronic, Engineering Manufacturing, Computer Science Software Engineering, Polymer Science, Construction Building Technology, Information Science Library Science, Engineering Industrial, Engineering Environmental, Geography, Computer Science Interdisciplinary Applications, Agriculture Multidisciplinary, Operations Research Management Science, Metallurgy Metallurgical Engineering, Computer Science Hardware Architecture, Law, Materials Science Multidisciplinary, Health Policy Services, Water Resources, Computer Science Information Systems, Education Educational Research, Materials Science Paper Wood, Mathematics Interdisciplinary Applications, Food Science Technology, Green Sustainable Science Technology, Environmental Sciences, Veterinary Sciences, Multidisciplinary Sciences, Agronomy, Telecommunications, Social Sciences Mathematical Methods, Energy Fuels, Horticulture, Acoustics, Business Finance, Chemistry Applied, Chemistry Multidisciplinary, Engineering Mechanical, Social Sciences Interdisciplinary, Mining Mineral Processing, Computer Science Artificial Intelligence, Instruments Instrumentation, Spectroscopy, Physics Applied, Education Scientific Disciplines, Engineering Chemical, Robotics, Ethics.

List A2. Measures corresponding to the different types of patent application characteristics

1. *Filing strategy*: country of filing of a patent, patent family size (count of national or international family members), patent belongs to an international family, occurrence of a paired publication with the patent, presence of a triadic patent in a family (a patent whose family comprises U.S., European, and Japanese patents), count or type of patents in a jurisdiction in a family (for example: divisional, continuation, or continuation-in-part patents in the U.S. or divisional patents in Europe), count of designated European Patent Convention (EPC) contracting states, count of priority filings, count of priority filings by geography, priority claim for a provisional application, domestic or Patent Cooperation Treaty (PCT) filing route, type of PCT filing based on the period between filing date and entry into the regional phase (type I: period is 20 months or less, type II: period exceeds 20 months), priority filing country, presence of a foreign priority, presence of a family member from a particular country, GDP-weighted patent family size, the ratio of patent family size to the number of countries where a patent was applied for, time span between the priority date and the filing date, time span between the first and last priority or filing dates in a patent family, time span between the filing dates of patent family members.
2. *Application claims*: Count of claims, count of words in the independent claims, count of characters in the first independent claim, difference between the number of claims (independent, dependent, or total) of a patent application and the corresponding granted patent.
3. *Disclosed content*: count of specific terms in the description, number of words describing the state of the art, number of words describing the technical problem, number of technical advantages, number of technical preferences, count of figures or drawings, count of words in the abstract, count of words in the complete specification, ratio of the number of words in the complete specification to claims, presence of particular words or phrases in the abstract, number of pages in the patent specification, readability measures of disclosure such as Gunning-Fog Index, Flesch-Kincaid Index, and the like, ratio of unique words to total number of words in the disclosure, disclosure of specific chemical or medicinal formulations
4. *Applicant cited literature*: count of cited patents or cited non-patent literature (at the level of the focal patent or its family); count, presence, or share of cited patents or cited non-

patent literature; count or share of cited patents by the applicant that are assigned to the same firm as the focal patent or to other entities; age of cited patents; count or share of cited patents by the applicant classified in the same or different technology class as the focal patent; type of non-patent literature (research article, conference proceeding, conference paper, or others); mean (or median) lag time between the application or grant year (or other reference year) of the focal patent and that of the cited patents or scientific literature (backward citation lag); count or share of cited patents by jurisdiction (country of filing of cited patents); presence of cited patents that do not cite any reference; type of citations labelled as X or Y in the examiner search report; or the ratio of cited patents to claims.

5. *Team composition*: count of inventors, or count or share of inventors by their country of residence, count or presence of inventors of academic origin (doctoral title holders or those affiliated to universities or other academic entities), country of inventor, presence of a person as the first inventor, number of co-inventors excluding a particular inventor, inventor (fixed effects).
6. *Ownership*: singular assignee, count or presence of co-assignees, type of assignment (public research institute, university, technology transfer office, government, foundation, firm, hospitals, or individual), country of assignee, size of filing entity based on record at patent office (small, large), type of assignment or co-assignment between entities categorized based on their business, operation, or specialization, assignee (fixed effects).

List A3. Measures corresponding to the different types of patent examination and grant characteristics

1. *Prosecution history*: decision to use "grace period" option in the U.S. for filing a patent application after having disclosed the invention to public, incidence of claim amendment prior-to the first office action, number of information disclosure statement (IDS) filings by the applicant at the patent office, incidence of an IDS filing by the applicant, accelerated search request by the applicant, accelerated examination request or other fast-tracking procedures by the applicant, request for continued examination by the applicant, choice of international preliminary examination authority following PCT filing by the applicant, filing of an appeal to the patent board by the applicant, seeking review from the patent board by the applicant, number of interviews requested by the applicant, issue of supplementary search report in response to request by the applicant, time span (days, months, or years) between the earliest priority date or filing date of a patent and its date of allowance or grant date (pendency time or grant lag), average pendency time of patents in a patent family, time span between the date of allowance and the grant date, time span between filing date and the first office action date, time span between the date of first office action or request for examination and the grant date, incidence of claim amendment at any point during prosecution, time span between the filing date and the publication date, number of examiner actions, number of responses to office actions by the applicant, number of transactions between the examiner and the applicant, number of rejections by the examiner, commercial databases used by the examiner for search, decision by the patent board, incidence of third party observations at the patent office prior to a patent grant, record of government interest in a patent, first action allowance of a patent application, year of first office action, patent term extension awarded by the patent office, nature of the person corresponding with the examiner (attorney, firm, patent agent, or third parry), and year of disposal of a patent case by an examiner.
2. *Granted claims*: count of claims (independent, dependent, or total), number of claims that incur extra filing fees, type of claims (machine, molecule, process, method, product, composition of matter, application, article, system, formulation), the ratio of dependent and independent claims, number of claim amendments during the examination, difference between the number of claims (independent, dependent, or total) of a patent application

and the corresponding granted patent, the difference between the number of words or characters in a claim of a patent application and its granted patent, total number of words in all the claims, "clarity" of claims based on linguistic features, presence of figures in claims, presence of Markush structure in claims, total number of alternatives covered by Markush structures, count of nouns in a claim; presence of functional limitations in claims, and count of words in the independent claims, count of characters in the first independent claim.

3. *External cited literature*: count, presence, or share of cited patents or non-patent literature by the examiner or a third party, type of citations labelled as X, Y, or A in the examiner search report.
4. *Technology scope:* count of unique first n-digit (typically 4 digits) International Patent Classification (IPC), Cooperative Patent Classification (CPC), United States Patent Classification (USPC), or European Patent Classification System (ECLA) sections, classes, or subclasses, share of declared IPC subclasses that belong to the main IPC class, IPC classes belonging to particular categories of interest, more than one IPC class, USPTO Technology Centre, categorization of the distribution of classes or subclasses into broad technologies to reflect the industry of operation of the focal patent (mostly used as a control variable).

List A4. Measures corresponding to the different types of post-grant patent characteristics as indicators of patent value

1. *Legal impact*: incidence or outcome of litigation, validity challenge in a court or a patent office, or opposition to patent grant, threat of litigation, reissue of a patent, damage awards in litigation, disputed at the International Trade Commission.
2. *Economic impact*: time to an event, probability of occurrence, success, or frequency of occurrence of an event such as licensing or renewal, renewal fees, termination of licensing, achievement of first sale of product or service from a licensed patent, commercialization of the patented invention, using the patent for founding a company, extent of profitability of an innovation, pledging as collateral to secure funding, sale of a patent in an internet marketplace, bidding of a patent in an auction, sale of a patent after a start-up goes bust, patent reassignment (or ownership transfer), reassignment based on nature of buyer (e.g., non-practising entity), the record of a security interest in a patent, regulatory (example, FDA) approval of a patented drug, or number of control rights held by the licensor in a license contract, exclusive or non-exclusive licensing, presence of a grant-back clause in a license, estimates of patent value from renewal model, estimates of patent value from stock market returns to firms, number of licensees of a patent included or prior to inclusion in a patent pool.
3. *Technological impact*: conferral of a prestigious award (Nobel Prize, National Inventor Hall of Fame in the US, Queen's Award in the UK, R&D100 Award by the R&D magazine), time to an event, probability of occurrence or success of an event, or frequency of occurrence of an event such as declaration of a patent as an essential patent to comply with a technical standard, labelling of a patent as "wacky" (for technical weirdness), inclusion of a patent in Woodcroft's Reference Index, inclusion of an essential patent in a patent pool, number of standard sections in a pool
4. *Knowledge internalization*: count or share of self-citing patents (citing patents from the same assignee as the focal patent), count or share of self-citing patents classified in the same or different technology class (based on IPC, CPC, or USPC technology codes) as the focal patent, count of self-citing patents (granted or otherwise) from the date of priority, filing, publication, or grant of the focal patent or its family to a study-defined cut-off time (generally 3-15 years window), citing patents by geography, yearly (single or multiple) rate

or average of citing patents, time elapsed from the patent grant date to the date of first forward citation (forward citation lag), ratio of citing patents in two periods of time, ratio of citing patents to claims, ratio of citing patents to patent family size, presence or absence of citing patents, count of self-citations prior to the event of maintenance, type of citations labelled as X, Y, A, or D in the examiner search report, count of citations from patents filed by small entities, count of citations from patents filed by individual inventors, adjusted measures (average or cumulative) of citations at the family level.

5. *Knowledge diffusion*: count or share of external citing patents (citing patents from assignees other than the assignee of the focal patent), count of citing patents excluding those having at least one inventor in common with the focal patent, count or share of citing patents classified in the same or different technology class (based on IPC, CPC, or USPC technology codes) as the focal patent, count of citing patents (granted or otherwise) from the date of priority, filing, publication, or grant of the focal patent or its family to a study-defined cut-off time (generally 3-15 years window), count of citing patents from a particular jurisdiction, yearly (single or multiple) count or average of citing patents, time elapsed from the patent grant date to the date of first forward citation (forward citation lag), ratio of citing patents in two periods of time, ratio of citing patents to claims, ratio of citing patents to patent family size, presence or absence of citing patents, count of citations prior to the event of maintenance, type of citations labelled as X, Y, A, or D in the examiner search report, count of citations from patents not having inventors from certain geographies, citations from patents filed by small entities, citations from patents filed by individual inventors, citations from patents filed by small entities without individual inventors, count or proportion of citations from examiners, count or proportion of citations from applicants, citations from a corporate or an academic assignee, adjusted measures (average or cumulative) of citations at the family level.

Table A1. Distribution of Papers Studying Patent Application and Examination-cum-Grant Characteristics*

Patent characteristic	Paper count	Paper codes
Filing strategy	123	DT19, HR03, TS19, GE13, GE08, HI04, MS11, RR04, FR14, CT11, KA19, LR08, SE16, CR13, HP17, LT14, HJ15, GR07, NT11, HE09B, HR07, BS12, HW20, CP16, MI19, MG11, DJ21, TW14, WI15, JE06, LS10, SJ11, AS09, GM03, GR10, GJ20, MJ12, CP11, FJ14, KR17, DR17, PM13, PR13, NJ11, KS15, YR15, KJ19, WP11, RS09, TS13, MR20, AD16, SI20, TR18, CJ06, LR13, vE11, WP15, CP14, BR16, SJ09, SS11, MR19, AJ19, YS15, CS17, HM09, LE20, AN18, SE21, JS21, KS21, KR21, ST21, CR22, BR07, CT20, FR10, HR21, LS17, LS08, LS07, MI21, PAT20, AT22, AM22, AR22, BE21, BR22, CJ22, GR22, SJ21, HJ21, PJ22, WR22, YS22, AR09, AI21, BSR20, CR18, CI08, CT16, CJ09, FT17, HDM09, KS18, KBR16, KS16, LE15, MRI21, MR09, MR15, NAE11, OJ20, OJ18, ST10, TR16, TR01, VR16, WP12, ZJ18, ZT20, ZE20
Application claims	9	MR19, KI19, PJ22, FA20, MRI21, OJ18, TR10, WR18, DR21
Disclosed content	10	RR04, MJ12, AN18, TR18, KR21, MJ21, YS22, CS19, KR11, ZT20
Applicant cited literature	198	DE16, HR03, TS19, AG04, GE13, vE11, BR08, GE08, HI04, LT01, RR04, FR14, KT16, SS12, SE16, MR05, SS03, CR13, GAE08, HP17, WP15, HJ15, LJ14, NT11, LJ04, HE09B, HD08, BR14, CP14, BS12, CP16, LJ10, LP14, MG11, PT15, NI20, TW14, WI15, WW19, LS10, AT15, SJ11, XA11, GR10, GJ20, MJ12, NS17, CP11, FJ14, DR17, PM13, PR13, KS15, SM10, GM08, YR15, KJ19, CO19, RI17, WP11, RS09, TS13, CR15, FM01, AI14, BR16, HM18, JJ20, PJ07, SI20, SR04, SS16, SJ18, TR18, CJ06, FS04, LR13, NE12, NR12, PA11, SJ09, SS11, GR14, AJ19, MR16, AN18, PS19, ZS21, AJ21, AR21, FT21, JS21, KS21, KT21, KR21, ZT21, BR07, AI18, CI13, CT20, CK09, CI11, HR21, LS17, LS08, LS07, MI21, MI20, NS07, PAT20, RT20, SR13, SS20, TP18, AT22, AM22, AR22, BR22, CR21, CS21, CJ22, GS21, GR22, HI21, HJ21, JT22, LT22, VA22, WQR22, YS22, AS16, AT16, AI21, AS13, BR20, BT15, BSR20, CJ17, CR18, CI08, CT16, CP20, CW18, CJ09, CE11, FJ21, FT17, FS17, FM17, GT14, HR16, HI17, HP18, HR19, HWR21, JC19, JA16, KR16, KJ13, KR11, KBR16, KS16, KO20, KT20, LO17, LJ18, LT12, LE15, MYI20, MR09, MR15, MJ14, MI18, MS17, NS03, NT20, NR15, OJ20, OJ18, PAJ18, PS06, RR18, ST10, SJ19, SR18, SM03, SS15, SP12, TR10, TJ11, TR01, WJ05, WP12, WR18, ZI17, ZJ18, ZT20, ZE20
Team composition	152	DT19, AG04, MS11, RR04, vE11, KA19, SS12, CR13, GE08, ZC12, HP17, LT14, ST18, HJ15, GAE08, LJ14, HE09B, HR07, BR14, CP16, MG11, PT15, NI20, DJ21, SE12, GM03, GR10, GJ20, CP11, DR17, PM13, KS15, SM10, SR08, YR15, RS09, SA13, TS13, JJ13, MR20, AD16, AI14, PJ07, SJ21, SI20, SJ18, TR18, AJ12, BB14, TS19, GR07, AT15, SS11, GJ17, MR16, AN18, PS19, ZS21, AJ21, CE21, FT21, KJ22, JS21, KS21, MJ21, SB21, ST21, ZT21, BR07, AI18, CI13, CT20, CK09, CI11, LS08, LS07, MI21, PAT20, RT20, SR13, SS20, TP18, AA22, BE21, BR22, CR21, CS21, CJ22, GS21, GR22, HI21, HJ21, JT22, NE21, VA22, WQR22, YS22, AS16, AR12, AT16, AI21, AS13, BS17, BT15, BSR20, CJ17, CJ17, CR18, CI08, CT16, CW18, CS18, CS19, FJ21, FT17, FS17, FM17, HR16, HI17, HS20, HP18, HR19, JC19, KR16, KBR16, KO20, MRI21, MYI20, MR09, MR15, MS17, NS03, NT10, NR11, NE11, NT20, NAE11, NE15, OJ20, OJ18, PAJ18, SJ19, SP10, SR18, SS15, SP12, SR07, TR16, WJ05, ZI17, ZJ18, ZT20
Ownership	101	LA08, RR04, SS12, CR13, ZC12, ST18, AT15, AS09, GJ20, CP11, BI18, PM13, RS09, JJ20, SI20, TR18, LE20, BJ21, FT21, JS21, MJ21, SB21, ST21, CR22, BR07, CI13, CT20, CK09, FR10, GMR14, LS17, LS08, LS07, LYA08, MI21, MI20, OA12, PT11, RT20, SI03, SR13, SS20, TP18, AM22, BR22, CR21, CJ22, GR22, LT22, MI22, SM22, WR22, YS22, AU08, AR09, AG10, AT16, AI21, AS13, BS17, BR20, BT15, BSR20, CJ17, CT16, CW18, CMR18, CA14, CJ09, CE11, FJ21, FT17, FM17, HS20, HP18, JC19, KR16, KJ13, KR11, KBR16, KO20,

Patent characteristic	Paper count	Paper codes
		KT20, LJ18, ME12, MJ14, MI18, NT18, NT10, NE11, NE15, RR18, SP12, SR07, TR10, TJ11, TR16, WJ05, WP12, ZI17, ZT20, LR13
Prosecution history	82	LA08, DT19, DE16, TS19, AG04, HI04, RR04, LA18, SS09, CR13, GR07, HJ15, MI19, MG11, TW14, HT14, JE06, SJ11, MJ12, MR19, NS17, CP11, DR21, KR17, DR17, GM08, YR15, RS09, QI08, HM18, SJ21, SS16, BB14, vE11, MS11, SS03, CS17, XA11, RJ10, NJ11, WP11, LR13, AN18, KS21, MJ21, BR07, AI18, CT20, CK09, FR10, LYA08, CR21, CJ22, GR22, HI21, PJ22, WR22, AU08, AT16, AI21, BSR20, CJ17, CW18, CS18, FJ21, FT17, FM17, HDM09, JC19, KR11, LB13, LE15, MRI21, NS03, PAJ18, RR18, SJ19, SP10, SS15, WR18, ZJ18, ZT20
Granted claims	182	DR21, MR19, DE16, AG04, GE13, vE11, GE08, HI04, LT01, MS11, RR04, FR14, CT11, KA19, KT16, LA18, LR08, SS12, SE16, MR05, SS03, GR07, HP17, ST18, WP15, HJ15, LJ14, LJ04, HE09B, HD08, CP14, BS12, HW20, CP16, LR19, LJ10, MI19, MG11, PT15, NI20, DJ21, SI10, TW14, WW19, HT14, JE06, LS10, AT15, XA11, GR10, GJ20, MJ12, CP11, HJ12, KR17, MJ17, PM13, PR13, RJ10, SM10, DI15, GM08, YR15, KJ19, RI17, WP11, JJ13, QI08, CR15, AD16, HM18, JJ20, PJ07, SJ21, SI20, SJ18, AJ12, LR13, NE12, NR12, PA11, SJ09, LA08, BR08, CR13, SJ11, BE15, DR17, TS13, LS20, AJ19, LE20, MR16, AN18, ZS21, AJ21, CE21, KJ22, JS21, KS21, KT21, KR21, MJ21, ZT21, CR22, TR13, AI18, CT20, HR21, LS17, LS08, LS07, LYA08, OA12, PAT20, SR13, SS20, TP18, AT22, AM22, AR22, BR22, CR21, CS21, CJ22, GS21, HI21, SJ21, HJ21, JT22, LT22, SM22, SS22, VA22, WR22, WQR22, YS22, AU08, AT16, AI21, AS13, BT15, BSR20, CJ17, CR18, CT16, CW18, CS19, CM20, CJ09, FT17, FA20, FM17, GT14, GA17, HP18, HR19, HWR21, JC19, JA16, KR16, KS18, KR11, KBR16, KS16, LE15, MRI21, MR09, MI18, NS03, NT20, NR15, OJ20, OJ18, PAJ18, RR18, SJ19, SP10, SP12, TR16, WJ05, ZT20
External cited literature	18	HI04, RR04, KT16, HE09B, SJ11, MJ12, NS17, TS13, AI18, CK09, WR22, AR09, JA16, OJ18, ST10, SS15, TR10, TR16
Technology scope	198	DT19, DE16, HR03, LA08, LT94, AG04, HI04, LT01, RR04, vE11, FR14, KT16, SS12, SS03, CR13, GR07, HP17, LT14, HJ15, LJ04, NT11, HE09B, BR14, HW20, CP16, MI19, MG11, PT15, NI20, DJ21, SI10, WI15, WW19, LS10, SJ11, AS09, CS17, GM03, GR10, GJ20, MJ12, NS17, CP11, FJ14, KR17, LS20, DR17, MJ17, PM13, ZI15, GM08, YR15, RI17, WP11, TS13, JJ13, CR15, FM01, AI14, PJ07, SJ21, SR04, SJ18, TR18, FS04, LR13, AT15, BR16, HT99, KQ17, DR21, NJ11, AJ19, GJ17, GE08, LJ14, JJ20, LE20, HE09, MR16, PS19, ZS21, AJ21, AR21, FT21, JS21, KS21, KT21, MJ21, SB21, ZT21, CR22, AI18, CI13, CT20, CK09, CI11, DM08, FR10, GMR14, HR21, LS17, LS07, LYA08, MI21, MI20, NS07, PAT20, RT20, SI03, SS20, AA22, AT22, AM22, AR22, BR22, CR21, CS21, GS21, HI21, KA21, LT22, PJ22, VA22, WR22, WQR22, YS22, AU08, AR09, AG10, AS16, AR12, AT16, AI21, AS13, AS06, BS17, BR20, BT15, BO14, CJ17, CR18, CI08, CT16, CW18, CA14, CJ09, CE11, FJ21, FT17, FM17, GT14, HR16, HI17, HP18, HR19, HWR21, JC19, KR16, KJ13, KR11, KS16, KO20, KT20, LO17, LJ18, LS14, MRI21, MYI20, ME12, MR09, MR15, MI18, MS17, NS03, NT10, NR11, NE11, NT20, NR15, OJ18, PAJ18, SJ19, SP10, SR18, SS15, SP12, SAR13, TJ11, TR16, TR01, VR16, WJ05, WP12, WR18, ZI17, ZJ18, ZT20

***** The references to coded papers are listed in appendix Table A4.

Table A2. Papers Studying the Direct Measures, Estimates, and Indicators of Patent Value*

Patent value measure	Paper count	Paper codes
Direct measure	9	NT11, FR14, HW20, SI10, LP14, MJ17, HR21, LE09, SP10
Estimate	20	HR03, RE04, HR07, GE08, TW14, GJ17, SS11, KQ17, AJ19, GE13, GR10, GR14, PS19, CR22, HR21, AM22, KA21, KR22, HKR21, HS20
Indicator: Legal impact	65	BR08, TS13, CP11, SJ11, JE06, HE09B, CR13, SE16, KT16, RR04, HI04, SJ09, SS16, YR15, DI15, KR17, HJ12, MJ12, GJ20, MG11, LJ10, LR19, CP16, BS12, CP14, WP15, HP17, SS03, MR05, SS12, LA18, LT01, AG04, LT94, SS11, PA11, AD16, KJ19, NS17, MI19, HD08, HR07, GR07, CT11, HR03, SJ18, KS21, TR13, CK09, AT22, SM22, AG10, CW18, CA14, CJ09, FA20, GT14, GA17, HP18, LS14, MI18, SP12, TR16, ZT20, ZE20
Indicator: Economic impact	116	DT19, DE16, LA08, vE11, BR08, ME05, KA19, LR08, ZC12, LT14, ST18, HJ15, LJ14, BS12, KI19, DJ21, WI15, HT14, SE12, WS10, ZI15, AJ19, KR20, SA13, TS13, QI08, KJ22, KT21, MS11, GR10, GR14, CS17, HE09, SJ18, SE12, RI17, PT15, PJ07, MJ18, MJ17, LS10, LP14, JJ13, HM18, GR07, GM08, FJ14, DR17, CJ06, AJ19, MR20, KJ19, CS17, MI19, SR10, HJ15, CT11, FR14, LE20, SE21, ZS21, MJ21, CR22, AI18, CT20, DM08, LS17, LS08, LYA08, MI21, NS07, SR13, SS20, TP18, WT15, AT22, AM22, CR21, GS21, HJ21, MI22, MS22, WQR22, YS22, BS17, BSR20, BJ10, CT16, CW18, CM20, CMR18, FA20, GA17, HDM09, HKR21, HP18, HWR21, KS18, KBR16, KT20, LB13, LO17, LE15, MRI21, ME12, NE11, NT20, NE15, OJ20, ST10, SP10, SR07, TR16, TR90, WP12, ZT20
Indicator: Technological impact	11	BR11, CE11, NT20, NAE11, VR16, DI15, MI19, BS12, CR22, BE15, AR21
Indicator: Knowledge internalization	201	DE16, HR03, AG04, GE13, TS19, LT94, BR08, GE08, HT99, HI04, HE09, ME05, MS11, FR14, KA19, LR08, SS12, SE16, MR05, SS03, CR13, GAE08, HP17, WP15, HJ15, LJ14, LJ04, NT11, KQ17, HE09B, HR07, HD08, SR10, BR14, CP14, CP16, LR19, LJ10, LP14, PT15, NI20, TW14, WW19, HT14, JE06, AT15, SJ11, AS09, BR11, CS17, GM03, GR10, GJ20, HM09, WS10, NS17, CP11, FJ14, MJ18, DR17, MJ17, PE06, PM13, PR13, KS15, SM10, SR08, DI15, YR15, AJ19, CO19, KJ19, KR20, WP11, SA13, TS13, CR15, FM01, AI14, BR16, HM18, PJ07, SJ21, SI20, SS16, SR04, SJ18, TR18, AJ12, CJ06, FS04, NE12, NR12, PA11, SJ09, SS11, BJ21, MR16, AN18, PS19, ZS21, AR21, CE21, KJ22, JS21, KS21, KT21, ST21, CR22, BR07, LR13, MI19, BS12, ST18, AI18, CI13, CT20, CK09, CI11, HR21, LS17, LS08, LS07, MR02, OA12, SI03, SS20, TP18, AA22, AM22, AR22, BR22, CR21, CS21, GS21, HI21, HJ21, KA21, KR22, LT22, MI22, MS22, SS22, WR22, WQR22, YS22, AG10, AR12, AI21, AS06, BS17, BR20, BT15, BSR20, BO14, CJ17, CR18, CI08, CT16, CW18, CJ09, CE11, FJ21, FT17, FS17, FM17, HR16, HI17, HP18, HR19, HWR21, JC19, KR16, KS18, KS16, LO17, LJ18, ME12, MR09, MR15, MJ14, MI18, NS03, NT10, NR11, NE11, NR15, OJ20, RR18, ST10, SJ19, SS15, SP12, SJ20, TJ11, TR90, TR01, WJ05, ZJ18, ZT20, ZE20
Indicator: Knowledge diffusion	218	DE16, HR03, AG04, GE13, TS19, LT94, vE11, BR08, GE08, HT99, HI04, HE09, LT01, ME05, MS11, FR14, CT11, KA19, LR08, SS12, SE16, MR05, SS03, CR13, GAE08, HP17, WP15, HJ15, LJ14, LJ04, NT11, KQ17, HE09B, HR07, HD08, SR10, BR14, CP14, CP16, LR19, LJ10, PT15, NI20, TW14, WW19, HT14, JE06, AT15, SJ11, SE12, AS09, BR11, CS17, GE05, GM03, GR10, GJ20, HM09, WS10, NS17, CP11, BE15, FJ14, MJ18, DR17, MJ17, PE06, PM13, PR13, RJ10, KS15, SM10, SR08, DI15, YR15, AJ19, CO19, KR20, WP11, SA13, TS13, CR15, FM01, AI14, BR16, HM18, SJ21, SI20, SS16, SR04, SJ18,

Patent value measure	Paper count	Paper codes
		TR18, AJ12, BB14, CJ06, FS04, NE12, NR12, PA11, SJ09, SS11, BJ21, MR16, AN18, PS19, SE21, PS19, AR21, CE21, KJ22, JS21, KS21, KR21, ST21, CR22, BR07, LR13, MI19, BS12, ST18, AI18, CI13, CT20, CK09, CI11, HR21, LS17, LS08, LS07, MI21, MI20, MR02, OA12, PT11, SI03, SR13, SS20, TP18, AA22, AM22, AR22, BR22, CR21, CS21, GS21, HI21, HJ21, JT22, KA21, KR22, MI22, MS22, SS22, VA22, WR22, WQR22, YS22, AG10, AS16, AR12, AI21, AS06, BS17, BR20, BT15, BSR20, BO14, CJ17, CR18, CI08, CT16, CW18, CJ09, CE11, FJ21, FT17, FS17, FM17, GT14, HDM09, HKR21, HR16, HI17, HP18, HR19, HWR21, JC19, KR16, KS18, KS16, LO17, LJ18, ME12, MR09, MR15, MI18, NS03, NT10, NR11, NE11, NR15, OJ20, PJ18, PAJ18, RR18, ST10, SJ19, SS15, SP12, SAR13, SJ20, TJ11, TR90, TR01, WJ05, ZJ18, ZT20, ZE20

* The direct measures and estimates of patent value are also obtained based on the legal or economic events that typify the indicators of patent value; nevertheless, they are presented separately here to highlight their importance as such measures are easier to compare across time and industries (see Kogan et al., 2017). The references to coded papers are listed in appendix Table A4.

Table A3. Papers Studying the Dimensions of Patent Quality*

Dimension of patent quality or value	Paper count	Paper codes
Subject matter	4	SC74, YS10, VI11, SW19
Utility	4	SC74, MC99, SN14, SW19
Non-obviousness or inventive step	5	SM74, SC74, VI11, SW19, PT20
Sufficiency of disclosure	5	FI08, SN10, SN16, SW19, SU08

***** The references to coded papers are listed in appendix Table A4.

Table A4. Correspondence Between Codes and References for Papers

Paper Code	Reference	Paper Code	Reference	Paper Code	Reference
DT19	(Danish et al., 2019)	LJ14	(Liu, 2014a)	SM74	(Sears, 1974)
DE16	(Drivas & Panagopoulos, 2016)	LJ04	(Lanjouw & Schankerman, 2004)	SC74	(Silverstein, 1974)
GJ17	(Gambardella, Harhoff, & Verspagen, 2017)	KQ17	(Kogan et al., 2017)	CR13	(Caviggioli, Scellato, & Ughetto, 2013)
HR03	(Harhoff et al., 2003)	HJ15	(Han & Sohn, 2015)	LA18	(Liu, Wu, & Lee, 2018)
TS19	(Tahmooresnejad & Beaudry, 2019)	LT01	(Lanjouw & Schankerman, 2001)	WP15	(Wu, Chang, et al., 2015)
NT11	(Nair, Mathew, & Nag, 2011)	ZE20	(Zingg & Elsner, 2020)	GR07	(Gambardella et al., 2007)
LA08	(Lee, 2008b)	CT11	(Chien, 2011)	GAE08	(Gay, Latham, & Le Bas, 2008)
LT94	(Lerner, 1994)	KA19	(Kabore & Park, 2019)	FR14	(Fischer & Leidinger, 2014)
SS11	(Schubert, 2011)	KT16	(Kapoor et al., 2016)	ZC12	(Zhang & Chen, 2012)
ZT20	(Zhang, Xiong, Duan, & Huang, 2020)	LR08	(Liu, Arthurs, Cullen, & Alexander, 2008)	HP17	(Huang et al., 2017)
AG04	(Allison, Lemley, Moore, & Trunkey, 2004)	ST18	(Sonmez, 2018)	AI18	(Ardito, 2018)
GE13	(Guo et al., 2013)	SS12	(Su, Chen, & Lee, 2012)	LE20	(Li, Chen, Jia, & Herrera-Viedma, 2021)
WJ05	(Waguespack & Birnir, 2005)	SE16	(Sterlacchini, 2016)	LT14	(Liu, Cao, & Song, 2014)
CJ06	(Chandy et al., 2006)	SS09	(Sternitzke, 2009)	FS04	(Fleming & Sorenson, 2004)
BR08	(Bessen, 2008)	SJ09	(Simcoe, Graham, & Feldman, 2009)	RR04	(Reitzig, 2004a)
GE08	(Gambardella, Harhoff, & Verspagen, 2008)	MC99	(Machin, 1999)	vE11	(van Zeebroeck & van Pottelsberghe de la Potterie, 2011a)
HT99	(Harhoff, Narin, Scherer, & Vopel, 1999)	MR05	(Marco, 2005)	LR13	(Liegsalz & Wagner, 2013)
HI04	(Harhoff & Reitzig, 2004)	SS03	(Somaya, 2003)	PA11	(Polidoro & Toh, 2011)
HE09	(Hegde & Sampat, 2009)	ME05	(Maurseth, 2005)	HE09B	(Hall, Thoma, & Torrisi, 2009)
SS22	(Song, Hou, & Zhang, 2022)	MS11	(Messinis, 2011)	NR12	(Nemet & Johnson, 2012)
HR07	(Harhoff & Hoisl, 2007)	BJ21	(Briggs, 2021)	HD08	(Hu, Bian, & Wang, 2008)
SR10	(Serrano, 2010)	ZJ18	(Zahringer, Kolympiris, & Kalaitzandonakes, 2018)	BR14	(Belderbos, Cassiman, Faems, Leten, & Van Looy, 2014)

Paper Code	Reference	Paper Code	Reference	Paper Code	Reference
CP14	(Chang, Hao, Chen, & Yuan, 2014)	TR01	(Trajtenberg, 2001)	NE12	(Nemet, 2012)
BB14	(Branstetter, Li, & Veloso, 2014)	BS12	(Baron & Delcamp, 2012)	HW20	(Hu, Yoshioka-Kobayashi, & Watanabe, 2020)
CP16	(Chang, Chen, Kiang, & Zhou, 2016)	KI19	(Kuhn & Thompson, 2019)	LR19	(Leiponen & Delcamp, 2019)
FM01	(Fleming, 2001)	LJ10	(Lerner, 2010)	LP14	(Liu, 2014b)
ZI17	(Zahringer, Kolympiris, & Kalaitzandonakes, 2017)	MI19	(Marco & Miller, 2019)	MG11	(McGahee, 2011)
PT15	(Petruzzelli, Natalicchio, & Garavelli, 2015)	NI20	(Noh & Lee, 2020a)	AJ12	(Alnuaimi, Singh, & George, 2012)
SJ18	(Su & Lin, 2018)	DJ21	(Danish, Ranjan, & Sharma, 2021)	SI10	(Sakakibara, 2010)
TW14	(Thoma, 2014)	WI15	(Wang, Lo, & Liao, 2015)	WW19	(Wittfoth, 2019)
YS15	(Yang et al., 2015)	MR20	(Maurseth & Svensson, 2020)	TR18	(Tong, Zhang, He, & Zhang, 2018)
FI08	(Fromer, 2008)	CR15	(Corredoira & Banerjee, 2015)	HT14	(Hikkerova, Kammoun, & Lantz, 2014)
JE06	(Jerak & Wagner, 2006)	AI14	(Arts & Veugelers, 2014)	LS10	(Lee & Lee, 2010)
AT15	(Petruzzelli, Rotolo, & Albino, 2015)	SJ11	(Schneider, 2011)	SE12	(Svensson, 2012)
SU08	(Seymore, 2008)	XA11	(Xie & Giles, 2011)	AS09	(Acosta, Coronado, & Fernández, 2009)
SJ21	(Schillebeeckx, Lin, George, & Alnuaimi, 2021)	SI20	(Seo, Kang, & Song, 2020)	BR11	(Bekkers, Bongard, & Nuvolari, 2011)
CS17	(Ciaramella, Martínez, & Ménière, 2017)	GE05	(Gay, Le Bas, Patel, & Touach, 2005)	GM03	(Gittelman & Kogut, 2003)
GR10	(Giummo, 2010)	GR14	(Giummo, 2014)	GJ20	(Gossart, Ozaygen, & Ozman, 2020)
HM09	(Hegde, Mowery, & Graham, 2009)	SN10	(Seymore, 2010)	MJ12	(Mann & Underweiser, 2012)
MR19	(Marco et al., 2019)	WS10	(Wang, Chiang, & Lin, 2010)	NS17	(Niidome, 2017)
BE15	(Baron & Delcamp, 2015)	TR90	(Trajtenberg, 1990)	YS10	(Yu, 2010)
DR21	(deGrazia, Pairolero, & Teodorescu, 2021)	VI11	(van Pottelsberghe de la Potterie, 2011)	CP11	(Caviggioli, 2011)
FJ14	(Fischer & Ringler, 2014)	HJ12	(Hemphill & Sampat, 2012)	KR17	(Kim & Oh, 2017)
SS16	(Somaya, 2016)	TR16	(Torrisi et al., 2016)	LS20	(Lo, Cho, & Wang, 2020)
MJ18	(Mann, 2018)	DR17	(De Marco, Scellato, Ughetto, & Caviggioli, 2017)	MJ17	(McCarthy & Ruckman, 2017)

Paper Code	Reference	Paper Code	Reference	Paper Code	Reference
PE06	(Popp, 2006)	BI18	(Briggs & Buehler, 2018)	PM13	(Park & Heo, 2013)
PR13	(Popp et al., 2013)	RJ10	(Régibeau & Rockett, 2010)	ZI15	(Zheng, Hu, & Hu, 2015)
NJ11	(Nikzad, 2011)	SN16	(Seymore, 2016)	SR04	(Sorenson & Fleming, 2004)
KS15	(Kaplan & Vakili, 2015)	SN14	(Seymore, 2014)	SW19	(Sipe, 2019)
SM10	(Singh & Fleming, 2010)	SR08	(Singh, 2008)	DI15	(Delcamp, 2015)
HM18	(Hegde & Luoc, 2018)	GM08	(Gans, Hsu, & Stern, 2008)	YR15	(Yamauchi & Nagaoka, 2015)
RE04	(Reitzig, 2004b)	AJ19	(Ashtor, 2019)	CO19	(Cirillo, 2019)
KJ19	(Kesan, Layne-Farrar, & Schwartz, 2019)	KR20	(Kuhn, Younge, & Marco, 2020)	JJ20	(Jung, 2020)
RI17	(Ruckman & McCarthy, 2017)	PJ07	(Palomeras, 2007)	WP11	(Wang & Lin, 2011)
RS09	(Reitzig & Puranam, 2009)	WR18	(Whalen, 2018)	SA13	(Svensson, 2013)
TS13	(Thoma, 2013)	TR13	(Tekic & Kukolj, 2013)	WP12	(Wang, Lo, Liao, & Lin, 2012)
JJ13	(Jeong, Lee, & Kim, 2013)	PT20	(Pedraza-Fariña & Whalen, 2020)	TJ11	(Thursby & Thursby, 2011)
VR16	(Verhoeven, Bakker, & Veugelers, 2016)	QI08	(Qiao, 2008)	AD16	(Allison & Ouellette, 2016)
BR16	(Battke, Schmidt, Stollenwerk, & Hoffmann, 2016)	MR16	(Mastrogiorgio & Gilsing, 2016)	AN18	(Ashtor, 2018)
PS19	(Poege, Harhoff, Gaessler, & Baruffaldi, 2019)	SE21	(Svensson, 2021)	ZS21	(Zhang, Chen, & Wang, 2021)
AJ21	(Ardito, Natalicchio, Appio, & Messeni Petruzzelli, 2021)	AR21	(Arts et al., 2021)	CE21	(Choi & Lee, 2021)
FT21	(Fabiano, Marcellusi, & Favato, 2021)	KJ22	(Khanna, 2022)	JS21	(Kim & Lee, 2021)
KS21	(Kim, Park, Lee, Jang, & Kang, 2021)	KT21	(Kwon, 2021)	KR21	(Kwon & Marco, 2021)
MJ21	(Ma, Zhu, & Liu, 2021b)	SB21	(Sommer & Ebersberger, 2021)	ST21	(Su, 2021)
ZT21	(Zhou, Gu, & Yang, 2021)	CR22	(Capponi, Martinelli, & Nuvolari, 2022)	BR07	(Burke & Reitzig, 2007)
CI13	(Callaert, Du Plessis, van Looy, & Debackere, 2013)	CT20	(Caviggioli, De Marco, Montobbio, & Ughetto, 2020)	CK09	(Czarnitzki, Hussinger, & Schneider, 2009)
CI11	(Czarnitzki, Hussinger, & Schneider, 2011a)	DM08	(Dechenaux, Goldfarb, Shane, & Thursby, 2008)	FR10	(Franzoni & Scellato, 2010)
GMR14	(Guerzoni, Taylor Aldridge, Audretsch, & Desai, 2014)	HR21	(Hsu, Hsu, Zhou, & Ziedonis, 2021)	LS17	(Lee & Sohn, 2017)
LS08	(Lee, 2008a)	LS07	(Lee, Lee, Song, & Lee, 2007)	LYA08	(Lee, 2008b)

Paper Code	Reference	Paper Code	Reference	Paper Code	Reference
MI21	(Martínez & Sterzi, 2021)	MI20	(Moreira & Soares, 2020)	MR02	(Mowery & Ziedonis, 2002)
NS07	(Nerkar & Shane, 2007)	OA12	(Otsuka, 2012)	PT11	(Petruzzelli, 2011)
PAT20	(Petruzzelli & Murgia, 2020)	RT20	(Rizzo, Barbieri, Ramaciotti, & Iannantuono, 2020)	SI03	(Sampat, Mowery, & Ziedonis, 2003)
SR13	(Sterzi, 2013)	SS20	(Sun, Zhang, & Kok, 2020)	TP18	(Tahmooresnejad & Beaudry, 2018)
WT15	(Wu, Welch, & Huang, 2015)	AA22	(Acemoglu, Akcigit, & Celik, 2022)	AT22	(Appio, Baglieri, Cesaroni, Spicuzza, & Donato, 2022)
AM22	(Arora, Belenzon, & Suh, 2022)	AR22	(Ashtor, 2022)	BE21	(Billington, 2021)
BR22	(Büttner et al., 2022)	CR21	(Chen, Shao, & Fan, 2021)	CS21	(Chen, Kim, & Miceli, 2021)
CJ22	(Choi & Yoon, 2022)	GS21	(Gandal, Shur-Ofry, Crystal, & Shilony, 2021)	GR22	(Gao & Zhang, 2022)
HI21	(Hou, Li, & Lin, 2021)	HJ21	(Hwang, Kim, & Jeong, 2021)	JT22	(Jiao, Wang, & Yang, 2022)
KA21	(Kelly, Papanikolaou, Seru, & Taddy, 2021)	KR22	(Krieger, Li, & Papanikolaou, 2022)	LT22	(Leone, Messeni Petruzzelli, & Natalicchio, 2022)
MI22	(Maamari & Osta, 2022)	MS22	(McGrath, Chen, & Nerkar, 2022)	NE21	(Nuvolari, Tartari, & Tranchero, 2021)
PJ22	(Petit, van Pottelsberghe de la Potterie, & Gimeno-Fabra, 2022)	SM22	(Seo, Kim, & Kim, 2022)	VA22	(Vestal & Danneels, 2022)
WR22	(Wagner, Sternitzke, & Walter, 2022)	WQR22	(Wang & Zheng, 2022)	YS22	(Yang, Zhang, Hu, & Wu, 2022)
AU08	(Abrams, 2008)	AR09	(Alcácer et al., 2009)	AG10	(Allison, 2010)
AS16	(Alnuaimi & George, 2016)	AR12	(Alnuaimi, Opsahl, & George, 2012)	AT16	(Ardito, Messeni Petruzzelli, & Panniello, 2016)
AT16	(Ardito et al., 2016)	AI21	(Ardito, Natalicchio, & Petruzzelli, 2021)	AS13	(Arts, Appio, & Van Looy, 2013)
AS06	(Atallah & Rodríguez, 2006)	BS17	(Bakker, 2017)	BR20	(Barbieri, Marzucchi, & Rizzo, 2020)
BT15	(Barirani, Beaudry, & Agard, 2015)	BSR20	(Baruffaldi & Simeth, 2020)	BO14	(Bhaskarabhatla & Hegde, 2014)
BJ10	(Burhop, 2010)	CJ17	(Capaldo, Lavie, & Messeni Petruzzelli, 2017)	CR18	(Cassiman, Veugelers, & Arts, 2018)
CI08	(Cassiman, Veugelers, & Zuniga, 2008)	CT16	(Caviggioli & Ughetto, 2016)	CP20	(Chai, Yang, Sui, & Chang, 2020)
CW18	(Choi & Cho, 2018)	CS18	(Choudhury & Haas, 2018)	CS19	(Choudhury & Kim, 2019)
CM20	(Christie, 2020)	CMR18	(Clancy, 2018)	CA14	(Cowart, Lirely, & Avery, 2014)
CJ09	(Cremers, 2009)	CE11	(Czarnitzki, Hussinger, & Schneider, 2011b)	FJ21	(Fallatah, 2021)

Paper Code	Reference	Paper Code	Reference	Paper Code	Reference
FT17	(Fan, Chang, Chang, Weng, & Lo, 2017)	FA20	(Feng & Jaravel, 2020)	FS17	(Ferguson & Carnabuci, 2017)
FM17	(Funk & Owen-Smith, 2017)	GT14	(Galasso & Schankerman, 2014)	GA17	(Grabowski, Brain, Taub, & Guha, 2017)
HDM09	(Harhoff & Wagner, 2009)	HKR21	(Higham et al., 2021)	HR16	(Hohberger, 2016)
HI17	(Hohberger, 2017)	HS20	(Huang, Duan, & Zhang, 2020)	HP18	(Huang, Su, & Shih, 2018)
HR19	(Huo, Motohashi, & Gong, 2019)	HWR21	(Hur & Oh, 2021)	JC19	(Jiang, Jefferson, Zucker, & Li, 2019)
JA16	(Jung & Lee, 2016)	KR16	(Keijl, Gilsing, Knoben, & Duysters, 2016)	KJ13	(Kelley, Ali, & Zahra, 2013)
KS18	(Khanna, Guler, & Nerkar, 2018)	KR11	(Khoury & Pleggenkuhle-Miles, 2011)	KBR16	(Kim, Kim, Miller, & Mahoney, 2016)
KS16	(Kim, 2016)	KO20	(Kneeland, Schilling, & Aharonson, 2020)	KT20	(Kwon, 2020)
LB13	(Lamoreaux, Sokoloff, & Sutthiphisal, 2013)	LO17	(Laursen, Moreira, Reichstein, & Leone, 2017)	LJ18	(Lee, Park, & Kang, 2018)
LT12	(Lee, Chiang, Wu, & Liu, 2012)	LS14	(Lemley, Li, & Urban, 2014)	LE15	(Lowe & Veloso, 2015)
MRI21	(Ma, Zhu, & Liu, 2021a)	MYI20	(Ma, Chi, & Song, 2020)	ME12	(Magazzini, Pammolli, & Riccaboni, 2012)
TJ20	(Tavakolizadeh-Ravari, Soheili, Makkizadeh, & Akrami, 2020)	MR09	(Martinez-Ruiz & Aluja-Banet, 2009)	MR15	(Melero & Palomeras, 2015)
MJ14	(Meyer & Subramaniam, 2014)	MI18	(Moaniba, Su, & Lee, 2018)	MS17	(Mukherjee, Romero, Jones, & Uzzi, 2017)
NT18	(Nan, Liu, & Ma, 2018)	NS03	(Nerkar, 2003)	NT10	(Nicholas, 2010)
NR11	(Nicholas, 2011)	NE11	(Nicholas, 2011)	NT20	(Noh & Lee, 2020b)
NR15	(Novelli, 2015)	NAE11	(Novelli, 2015)	NE15	(Nuvolari & Vasta, 2015)
OJ20	(Og, Pawelec, Kim, Paprocki, & Jeong, 2020)	OJ18	(Okada, Naito, & Nagaoka, 2018)	PJ18	(Park, Howard, & Gomulya, 2018)
PAJ18	(Petruzzelli, Lorenzo, & Tommaso, 2018)	PS06	(Phene, Fladmoe-Lindquist, & Marsh, 2006)	RR18	(Raiteri, 2018)
ST10	(Sampat, 2010)	SJ19	(Schillebeeckx, Lin, & George, 2019)	SP10	(Shyam, Mathew, & Nag, 2010)
SR18	(Silvestri, Riccaboni, & Della Malva, 2018)	SM03	(Song, Almeida, & Wu, 2003)	SS15	(Steensma, Chari, & Heidl, 2015)
SP12	(Su, Lee, Chen, & Chiu, 2012)	SAR13	(Subramanian, Lim, & Soh, 2013)	SR07	(Svensson, 2007)
TR10	(Tan & Roberts, 2010)				

3 Study 2

The Economics of Patent Scope: An Empirical Study

Abstract

Patent scope is an important point in discussions of innovation and patent policy. The optimality of patent scope is a critical factor that maximizes the benefits to innovators at a minimum social cost. Based on the analysis of a large data of US granted patents, I contribute to the literature in the field of innovation economics by explicating a valid, robust, and complementary measure of patent scope by identifying specific and commonly used scope-related terms in the patent claims that are consistently interpreted by the patent office and courts and traditionally used by practitioners. I find that innovators use these scope-related terms in the claims strategically to broaden the scope of the patent at grant whilst the examiners typically curtail the scope by decreasing the independent claims count or increasing the number of words per independent claim. My findings benefit practitioners by informing them of the economic significance of the use of scope-related terms in patent claims: on average, all things remaining the same, for patents assigned to public listed firms, one additional open-ended scope term per independent claim corresponds to an 8.5 percent increase in the estimated dollar value of the patent at grant. The study contributes to the policy debate in the US on the "quality" of patents. My findings are suggestive of systemic issues in legally authorizing patents with an overly broad scope.

Keywords: patent scope, innovation economics, claim interpretation, strategic use, patent value, patent quality

3.1 Introduction

A patent system is central to a nation's policies that promote technological progress. Patents offer a grand bargain to innovators by providing a temporary monopoly in exchange for public disclosure of inventive knowledge to facilitate technological dissemination. Patent scope and patent duration are policy levers of great economic significance; several influential theoretical papers demonstrate how the different combinations of these two variables maximize social welfare. Gilbert and Shapiro (1990) define patent 'breadth' as the ability of the patentee to raise the price for a single patented product and find that an optimal patent policy would require the patents to have an infinite life and narrow breadth. Defining patent scope as the region of differentiated product space protected by the patent, Klemperer (1990) concurs with Gilbert and Shapiro under certain conditions and finds that broad-scoped, short-lived patents are optimal under different conditions. Gallini (1992) (also discussed in Gallini & Scotchmer, 2002) introduces imitation costs into the economic theory of patents. By measuring patent scope as the flow of profits earned by an innovator, Gallini shows that social surplus is maximized when patents are broad (without imitation) and patent life is adjusted to achieve the desired patent award. Gilbert and Shapiro inform that though patent scope can have different meanings, any definition would encompass the idea that broader patents are associated with a higher private value.

Since the statutory duration of a patent is fixed, the role of patent scope as a policy lever deserves more empirical attention (see Merges & Nelson, 1990). Marco, Sarnoff et al. (2019) inform that though all patent systems use legal doctrines to regulate patent scope, the discussion of scope as a policy instrument remains largely theoretical. Kitch (1977) explains the scope of a patent as embodied in the claims would be broader than that of the underlying invention since the former represents an abstraction and generalization of an indefinitely large number of real-world objects, and he argues for broader patent scope for inventions with more future "prospects" as such a patent would enable the innovator to continue with the development of the invention without the fear of external encroachment (also see Merges & Nelson, 1994). Notwithstanding the nature of the invention, an innovator would always want the broadest possible scope for a patent at grant; the patent office uses its discretionary powers to decide how broad this scope should be (Merges & Nelson, 1990). Marco, Sarnoff et al. (2019) inform that patents issued with an *overly* broad scope relative to the inventive contribution are reflective of "poor quality" and these could seriously hurt subsequent innovation and undermine the role of the patent system in the economy.

Though patents protect isolated innovations, Scotchmer (1991) informs research is cumulative in the sense that subsequent research focuses on improvements and applications of previous discoveries. Here again, patent scope plays a pivotal role (Gallini & Scotchmer, 2002; Scotchmer, 1991): the statutory life of a patent becomes irrelevant when a non-infringing substitute, such as an improvement, displaces the patented product from the market; of importance then is the effective life of a patent which is the time until the non-infringing substitute appears, which in turn depends on the scope of the prior patent. Green and Scotchmer (1995) find that patent scope is a key factor that determines the division of profits in markets characterized by sequential innovations. Gallini and Scotchmer (2002) cite a historical example that's suggestive of the perils of patents with too broad scope: As James Watt refused to license his patents on the steam engine for improvements, there was a deluge of the pent-up invention after the patents' expiry. Based on cases in the cumulative systems technology, Merges and Nelson (1994) argue that within the limits of patent law, the scope of a patent should be kept tight for innovations that open broad prospects and conclude in a connected paper (Merges & Nelson, 1990) that without extensively reducing the pioneer's incentives, patent law should favor a competitive environment for improvements compared to an environment where the pioneer's firm is dominant.

In empirical studies, patent scope is mostly measured (see Novelli, 2015) based on the number of claims (Tong & Frame, 1994) and the number of examiner-assigned technology classes (Lerner, 1994). More recent measures include the average number of words per independent claim (Kuhn & Thompson, 2019; Marco et al., 2019) and that derived based on the complex dependencies among the patent claims (Wittfoth, 2019). The claim is a patent's most important element as it contains the information most relevant to the scope of the invention; any direct measure of patent scope would have to be based on the claims (see Cotropia, 2005; Marco et al., 2019). Further, scope measures based on patent claims provide the additional benefit of being able to study the changes in scope between a granted patent and its pre-grant publication which could be used to get insights into the patent examination process (Marco et al., 2019). Cotropia (2005) comments that notwithstanding the relevance of claims to patent scope, they are written using terms that in isolation are useless as they must be *interpreted* to make sense. In an early theoretical paper that highlights the importance of claim interpretation to patent scope, Chang (1995) posits that courts dealing with patent infringement cases involving basic inventions should extend a broad scope of protection to these inventions even when the invention's value relative to that of the improvements (allegedly infringing products) is minuscule.

Williams (2017) informs that the difficulty in interpreting patent claims is the reason why patent scope as a concept is challenging to define and measure and why the traditionally used scope measures such as the number of claims and the number of words per claim have limited applicability. Though Marco, Sarnoff et al. (2019) and Kuhn and Thompson (2019) independently explicate the number of words per independent claim as an indicator of patent scope along the language dimension of claims, admittedly, the measure is inconsistent with the rationale underpinning its construction that the *longer* the claims (or the more the number of words in a claim), the *narrower* the claim scope. Specifically, for a subset of patents in the chemicals, drugs, and biotechnological domains that are frequently drafted using a special Markush language (see Simmons, 1991), *shorter* claims are associated with a *narrower* scope.[1] This ambiguity excludes from such patent scope measurements, a substantial and economically important set of patents belonging to the chemical, medical, and biotechnology fields (see Cohen, Nelson, & Walsh, 2000; Lerner, 1994) wherein Markush claim language is frequently used (see Section 2117 in Manual of Patent Examining Procedure USPTO, 2020b), and consequently, reduces the generalizability of this scope measure.

My objective is to enhance the understanding of how the claim language can be used to obtain a valid, unambiguous, and broadly applicable measure of patent scope. Accordingly, I seek answers to my related *research questions: (1) how to measure patent scope based on claim interpretation? and (2) what is the effect of this patent scope measure on the private value of patents?* In my empirical setting, relying on the examination guidelines provided in the US patent statute, I identify specific scope-related terms in the patent claims that have unambiguous meaning and common usage. I use a text mining algorithm to construct my measure of patent scope for a large sample of US patents. To enhance the robustness of my inferences, I study several established indicators of the private value of a patent such as the number of self-citations to a patent, the

[1] To explain this logic, consider the set of hypothetical Markush claims: (1) A process employing a catalyst selected from the group consisting of iron, cobalt, and nickel; and (2) A process employing a catalyst selected from the group consisting of iron, cobalt, nickel, and zinc. Though claim (2) has more words than claim (1), it's also broader in scope as it includes an additional possibility of zinc as a catalyst.

estimated dollar value of a patent at issuance, and the incidence of litigation, reassignment, or collateralization of a patent.

The study makes several important contributions. First, as a methodological contribution to the literature on innovation economics, it explicates a valid, stable, and complementary measure of patent scope. The measure is valid on three counts: (a) I construct the measure from certain specific, traditionally used scope-related terms by practitioners in the patent claims that are identified based on their consistent construal by the patent office and the courts in the US, (b) on a random sample of 100 patents, a manual check reveals that value of the scope measure from the text mining algorithm matches with the actual value in 99 patents, and (c) consistent with theoretical predictions, I find the scope measure is positively and significantly ($p < .05$) associated with multiple indicators of patent value. The stability of my measure is indicated by the nonfluctuating sign of the coefficients in the regression models. My scope measure is also complementary to perhaps the most reliable and direct patent scope measure, the number of patent (independent) claims, as the former captures the variation in patent scope along the hitherto untapped but very important dimension of claim interpretation. Second, the empirical contribution stems from identifying and validating a hitherto unknown yet important subdimension of patent scope which is related to the meaning of certain words in the claims of patents.

Third, the study contributes to management practice in multiple ways. The trend analysis of my scope measure indicates that innovators use the scope-related terms in patent claims to broaden the patent scope in two stages: strategically at the patent application stage and tactically during the patent examination whilst the patent examiners (consistent with the standards of patentability) typically curtail the overall scope of the patent by decreasing the number of independent claims or increasing the number of words in an independent claim. This finding would enlighten managers on the strategic and tactical usage of the scope-related terms in the patent claims to maximize the overall scope of a patent at issuance. The effect of my scope measure on the private value of patents is also economically significant. For example, on a subset of patents assigned to publicly listed firms in my sample, all things remaining the same, an increase in one open-ended scope term per independent claim corresponds to an 8.5 percent increase in the estimated dollar value of the patent. The knowledge of my scope measure would also enable a reasonably accurate assessment of patent value and facilitate well-founded decisions on patents such as the licensing, transfer, or collateralization of the patents in the technology markets.

Fourth, the study contributes to the patent policy debate in the US on the "quality" of issued patents (see Marco et al., 2019). The trend analysis of my scope measure during the grant year range of 2005-2014 suggests that (a) for granted patents, the measure is *increasing*, and (b) the measure for a granted patent *exceeds* that for its pre-grant publication in each grant year. This finding contrasts with that of Marco, Sarnoff et al. (2019) for the other claim-based scope measures such as the number of independent claims or the average number of words per independent claim; the authors attribute the observation to the "stringency" of patent examination following the various patent quality improvement initiatives at the USPTO since 2004. My contrasting finding stands to invigorate the patent quality debate. I believe that since the USPTO explicitly lays down rules on how to interpret the scope-related terms in the claims, the presence of these terms in patents justifies the patentability standards. My findings are suggestive of systemic issues in legally authorizing patents with an overly broad scope.

In section 3.2, I discuss the theory and conceptual framework for the study. In section 3.3, I describe the data collection strategy and the text-mining algorithm I use to construct my research variable, demonstrate the validity of the algorithm, and justify the choice of the response and control variables in my regression models. In section 3.4, I present the results of my study and integrate these with a discussion of the significant findings. Herein, I attempt to mitigate the endogeneity concern in my models by adopting an instrumental variable approach. In section 3.5, I provide the conclusions and policy and managerial implications of my work. I wrap up the paper by discussing the limitations of the study and potential opportunities for future research.

3.2 Theory And Conceptual Framework

A successful patent disclosure plausibly reflects the innovator's appraisal of the "quality" of the underlying invention that exceeds a minimum threshold such that the appropriation from the patent would justify the patent disclosure. Appropriation is the degree to which an innovator captures the value created from the patented innovations (Ceccagnoli, 2009; Hurmelinna-Laukkanen & Yang, 2022). Value-appropriation could be direct when the exclusionary rights from a patent are used to prevent imitation by competitors, indirect when the patent rights are transferred, licensed, or sold in the markets for technology (for example, when the innovators lack the complementary manufacturing or marketing assets), or strategic when broad patents are held to develop the innovator's foundational technologies in the future (Kitch, 1977) or to pre-empt R&D rivals by foreclosing their ability to introduce substitutes and compete with the innovator's core technologies (Ceccagnoli, 2009; Cohen et al., 2000).

I adapt the definition of patent scope by Klemperer (1990) as the region of differentiated feature (product, process, or system) space protected by a patent and the definition of Giummo (2010) for the private value of a patent as the sum of the value of the patented invention's use as an asset and the value of the right to exclude others from the use of the patented invention. As my measure of patent scope is obtained from patent claims, the terms ‘patent scope’ and ‘claim scope’ (though technically different) have the same contextual meaning.

Pre-grant patent characteristics such as patent scope measures are operationalized as ex-ante indicators of patent quality (see Higham et al., 2021). Gilbert and Shapiro (1990) inform that the concept of patent scope can have different meanings to different stakeholders, but any definition would capture the core idea that a *broader* patent scope is associated with a *higher* value for the patent. The emergent ex-ante theory of patent value posits a direct and positive relationship between patent quality and patent value (Perel, 2014). Nomological validity (see O'Leary-Kelly & J. Vokurka, 1998) is the determination of the extent to which constructs are related in a theoretically predictable manner. To establish the nomological validity of my scope measure, consistent with the logic adopted by Lerner (1994) and Marco, Sarnoff et al. (2019) and with the proposition of the ex-ante theory of patent value, I formulate my research hypothesis as:

H: Ceteris paribus, the broader the patent scope the higher the private value of the patent.

3.3 Research Strategy

3.3.1 Data Collection

As my focus is the analysis of patent claims in English, I choose the most representative and widely studied patent office in the world in this respect – the United States Patent and Trademark Office (USPTO). Consistent with the literature in the field of innovation economics, I choose utility patents as the sample for my study and a granted patent as the unit of observation and analysis. The grant year range of the patents in the sample is 2001-2014. The year 2001 is chosen as the first year of patent grant as the information on the origination of the patent (a key control variable

Origin in my regression models) is not available before 2000 in my data sources. The choice of 2014 as the last year of the patent grant is because the text data on patent claims is available only until 2014 in my data sources.

I obtain the data from three sources — the USPTO, Clarivate, and PatentsView. The USPTO periodically releases patent datasets for academic research; among them, the following are used: (1) Patent Examination Research Dataset (Graham et al., 2015) containing the information on the examination of US patents published through 2019; (2) Patent Litigation Dataset (Marco, Tesfayesus, et al., 2017) containing the litigation data of US patents obtained from unique district court cases filed during 1963-2016; (3) Patent Claims Research Dataset (Marco et al., 2016) containing the information on the claims for US patents granted during 1976-2014 and US applications published during 2001-2014; and (4) Patent Assignment Dataset (Marco et al., 2015) comprising information on patent reassignments and security interest agreements recorded at the USPTO since 1970. PatentsView is a data visualization, bulk download, and analysis platform supported by the USPTO that I primarily use to obtain the data on citations and the National Bureau of Economic Research (NBER) technology category of patents (Hall et al., 2001). I use Clarivate to extract information on the family composition (see Martinez, 2011) of the patents in my sample. I merge the patents obtained from these multiple sources by patent number, clean the data to remove the records with missing or erroneous values, and exclude design and reissue patents; following these operations, my preliminary research sample has 2,427,508 patents.

3.3.2 Operationalization

I refer to the US patent statute's rules on claim interpretation (MPEP § 2111 USPTO, 2020c) to identify terms in patent claims that specifically relate to patent scope to construct my research variable. In appendix B, I provide the details of the relevant sections in the US patent statute. Essentially, the claim terms 'comprising', 'including', 'containing', and 'characterized' are open-ended as each of these terms is interpreted to be inclusive of the additional elements *not* specified in a claim, whereas the claim term 'consisting' is close-ended as it's interpreted to exclude elements not specified in a claim.[2] This means *ceteris paribus*, a higher frequency of the open-ended scope terms in a claim would make the claim broader in scope.[3] The validity of the open-ended scope terms in my research variable construction stems from the fact that the US patent doctrine (MPEP § 2111 USPTO, 2020c) cites several case laws wherein the construal by the courts of these terms in the claims is unambiguous and consistent with that by the patent office. It's also remarkable that these terms have particularly established meanings among practitioners based on decades of their consistent usage in claims drafting (see Menell et al., 2010).

In the next step, I first obtain the sum of the frequencies of occurrence of each of the open-ended scope terms in the independent patent claims in my research sample using a text-mining algorithm in R statistical programming language and then calculate the average (arithmetic mean) of this sum per independent claim; I name this variable as *Scope*.[4] The algorithm used in R Console (the

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[2] We find evidence in patents that the words 'comprised', 'comprises', 'includes, and 'contains' are also included in the claims less regularly. At first blush, these words might seem equivalent in meaning to the open-ended scope terms that we include in our research variable construction; in the absence of a legal rule in the US that supports this equivalency premise, our study considers these apparently equivalent terms as having null scope along the claim interpretation dimension.

[3] During our analysis, we find (something not explicit in the patent statute) that the scope-related terms in the patent claims are used in different parts of the same claim. E.g., the first claim of the patent US 6,168,805 (assigned to Endo Pharmaceuticals Inc.) recites:

> "A process for preparing solid, amorphous paroxetine comprising: (A) mixing paroxetine free base or a pharmaceutically acceptable paroxetine salt with water and pharmaceutically acceptable polymer; and (B) drying to form a composition comprising solid amorphous paroxetine and polymer wherein said polymer is at least partially water-soluble."

Given this finding, we do not distinguish between the location of the scope-related terms in the claims and consider all of them as equally relevant in our variable construction.

[4] We only consider the independent claims as according to the claims drafting convention, the independent claims are the broadest in terms of the scope of protection with the dependent claims protecting the narrower and specific

statistical environment used for data analysis) for the construction of *Scope* variable is summarized below.

1. Load patent data with information on the *text* of claims (dependent as well as independent) for patents granted in 2001 (source: PatentsView database) (R function: 'fread');
2. Identify the variable that contains the text of each claim for each patent in the data from step 1 (results in multiple observations per patent);
3. Identify the variable that contains the information on the nature of claims — dependent or independent — for each patent in the data from step 1;
4. Subset the data from step 3 to exclude observations (or rows) with dependent claims (R function: 'subset');
5. Create a variable to count the *open-ended* scope terms in *each* independent claim for each patent in the data from step 4 (R function: 'str_count', R package 'tidyverse');
6. Repeat step 5 for *close-ended* scope terms;
7. Create a variable to *add* the count of the *open-ended* scope terms in *all* the independent claims for each patent in the data from step 4 (R function: 'group_by', R package 'dplyr');
8. Repeat step 7 for *close-ended* scope terms;
9. Reduce the data from step 8 by excluding observations with identical patent numbers (results in single observation per patent) (R function: 'summarise', R package 'tidyverse');
10. Load patent data with information on the *count* of claims (dependent as well as independent) for patents granted in 2001 (source: Patent Claims Research Dataset) (R function: 'fread');

embodiments of the claimed invention. To obtain *Scope*, we extract the text of the independent claims that's available in a parsed format as such from the PatentsView database.

11. Identify the variable that contains the count of *all independent* claims for each patent in the data from step 10;
12. Merge the datasets from steps 9 and 11 by patent number as the common identifier (R function: 'vlookup');
13. Create *Scope* variable by taking the ratio of the sum of count of *open-ended* scope terms in *all* the independent claims for each patent from step 7 and the count of *all independent* claims for each patent from step 11;
14. Repeat step 13 to create a temporary variable for *close-ended* scope terms; and
15. Create a variable to identify patents that *do not have any* open-ended or close-ended scope terms (the variables from step 13 (*Scope*) and 14 will have the value of zero for these observations).
16. Repeat steps 1 through 15 for each year of patent grant from 2002 through 2014.

To authenticate my text-mining method, I draw a random subset of 100 patents from my research sample and crosscheck the algorithm-generated frequencies of both the open-ended and close-ended scope terms against the corresponding actual counts. The algorithm-generated measures match with the actual in 99 out of the 100 patents. The one patent with a mismatch has a claim vaguely written in a way that cannot be identified as dependent or independent.[5] Hence, *Scope* calculations have a small idiosyncratic error component.

On analysis of *Scope*, patents having at least one open-ended scope term in an independent claim constitute 96.5 percent of my sample patents. Patents having none of the open-ended scope terms

[5] Claim 6 of US 6,908,010 B2 reads as: <u>A</u> recording apparatus comprising: a recording unit for recording on a recording medium; and a sheet material conveying apparatus <u>as set forth in any one of claims</u> 3 <u>to 5</u> for conveying the recording medium.

in the independent claims but having at least one close-ended scope term ('consisting') therein constitute 1.0 percent of the sample; by default, these patents have a null value for *Scope*. The remainder of patents are expected to have uncommon scope-related terms in their claims that the US patent statute (MPEP § 2111 USPTO, 2020c) informs should be interpreted on a case-by-case basis; after excluding these patents as outliers, my final research sample has 2,368,474 patents.

I choose five measures of the private value of a patent to make robust inferences from my findings. First, (forward) citations to a patent (Trajtenberg, 1990) are extensively studied as indicators of patent value. The citations originate from patents assigned to the same firm as the cited patent (self-citations) or otherwise (examiner or external citations). Hall, Jaffe et al. inform (2005) that self-citations are indicative of an innovator's strong competitive position in the technology specific to the cited patent. Accordingly, I use self-citations as an indicator of the private value of a patent and operationalize *Self-citations* as the total count of citing US-granted patents having the same assignee as the cited patent.[6] Second, I obtain the estimates of the U.S. dollar value of patents that are assigned to publicly listed firms (see Kogan et al., 2017); this information is available for a subset of 992,284 patents in my sample. The variable *Value* is the dollar estimate of the real value of a patent which is the nominal value deflated to 1982 (million) dollars.[7]

Third, disputes regarding patent rights are litigated in court and because of the enormous costs associated with litigation, innovators litigate only the economically important patents (Lerner, 1994). Accordingly, *Litigation* is a binary response variable that is assigned values of 1 or 0 based on whether a patent is litigated or not. Fourth, patent reassignment is an agreement that transfers

[6] The count of self-citations is taken directly from PatentsView database.
[7] I accessed the dollar estimates of patents from Kogan, Papanikolaou et al. (2017) here: https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data. Date of access: 20 March 2022

all interests in a patent from an existing owner to a recipient (Graham, Marco, & Myers, 2018; Serrano, 2010). I use *Reassign* as a binary variable that takes values of 1 or 0 based on whether a patent is subject to a firm-to-firm reassignment or not (this specific information is available from the Patent Assignment Dataset). As this variable is relevant to patents assigned to firms alone, I exclude patents categorized as academic from my research sample (using *Assignee* variable, see details below) that yields a subset of 2,230,993 patents for reassignment analysis. Finally, patents as intangible assets can be securitized - pledged as collateral for debt - wherein a third-party lender takes an interest in a patent to secure payment on a loan (Graham et al., 2018). Securitization of patents helps resource-constrained firms access debt financing (Fischer & Ringler, 2014). *Security* is a binary variable that takes values of 1 or 0 based on whether a patent is securitized or not (information obtained from the Patent Assignment Dataset).

As one set of patent-level control variables, I include three comparative measures of patent scope. Patent claims are of two types, dependent and independent. As dependent claims, by definition, cover subject matter that is a proper subset of that covered by the parent independent claim, I use the count of independent claims (*Claims Count*) as an indicator of the magnitude of the inventive step (de Rassenfosse & Jaffe, 2018). I include the average number of words per independent claim (*Claim Length*) as an indicator of the narrowness of the invention (Marco et al., 2019) and the number of unique 4-digit international patent classification (IPC) technology classes assigned by the examiner (*Patent Classes*) as an indicator of the technological breadth of the patent (Lerner, 1994). I also include other patent quality proxies that control for invention quality or patent value such as the count of cited patents (*Cited Patents*) that captures the extent of patenting activity in a particular technical field and hence the potential profitability of inventions in that field (Harhoff & Reitzig, 2004); the number of inventors (*Inventors*) in a patent that's a reflection of the diversity and size of the knowledge pool that could directly affect the patent's relevance (Petruzzelli, Rotolo, et al., 2015); and the number of countries or geographies where the patent was applied for protection (*Family*) that's an indication of the value of the invention as international patent application processes are costly (Lanjouw, Pakes, & Putnam, 1998). The age of a patent measured as the number of years elapsed from its grant year until 2019 inclusive (*Age*) controls for the post-grant time-sensitivity of each of my response variables except *Value*.

The NBER technology category of patents (*Technology*) is a dummy variable that controls for the systematic variation in patent quality or value across the broad technological categories of computers & telecommunication, electronics & electrical, mechanical, chemical, drugs & medical, and others (Hall et al., 2001). *Origin* is a dummy variable that controls for the "relatedness" among patents in my sample (Hegde et al., 2009) because the USPTO allows for the filing of continuing patent applications under the designations of continuation applications (CAP), continuation-in-part applications (CIP), and divisional applications (DIV); in the same variable, I also categorize patents into those originating from a patent cooperation treaty (PCT) application, provisional, or a non-provisional application. I use two assignee-level dummies to control for the variation in invention quality or patent value at a more macro level such as the size of the filing entity (discounted or undiscounted as determined by the USPTO) (*Entity*) (Alcácer et al., 2009) or the academic or corporate nature of the assignee (*Assignee*) (Trajtenberg, Henderson, & Jaffe, 1997).[8] I employ patent grant year fixed effects (*Gt Year*) to control for the variation in invention quality or patent value due to events that may have occurred in the individual years of the patent grant (see Nemet & Johnson, 2012). The composition of the sample in terms of research, response and

[8] This classification is based on a text-mining technique implemented in R to classify the names of assignees with terms such as university, institute, government, academic, hospital, college, school, or foundation as academic. This classification slots all the academic-corporate jointly assigned patents to the category of academic.

control variables along with the source database for each variable is presented in Table 3.1. All the variables for each observation in the sample are linked by a corresponding common identifier — the patent number. The final research sample is panel data which is analyzed in the next section.

Table 3.1. Composition of the Sample and Source

Variable	Source	Type	Subtype
Self-citations	PatentsView	*R*	-
Litigation	Patent Litigation Dataset	*R*	-
Reassign	Patent Assignment Dataset	*R*	-
Security	Patent Assignment Dataset	*R*	-
Value	Kogan	*R*	-
Scope	PatentsView	*P*	*RV*
Claims Count	Patent Claims Research Dataset	*P*	*CV*
Claim Length	Patent Claims Research Dataset	*P*	*CV*
Patent Classes	Clarivate	*P*	*CV*
Cited Patents	Clarivate	*P*	*CV*
Inventors	Clarivate	*P*	*CV*
Family	Clarivate	*P*	*CV*
Technology	PatentsView	*P*	*CV*
Origin	Patent Examination Research Dataset	*P*	*CV*
Entity	Patent Examination Research Dataset	*P*	*CV*
Assignee	Patent Examination Research Dataset	*P*	*CV*
Gt Year	Patent Examination Research Dataset	*P*	*CV*
Age	-	*P*	*CV*

Notes. This table presents the details of the variables in terms of their source, type, and subtype used in the study. The column Source provides information on the database from which each variable is obtained. Under column Type, the notation *R* means response variable and *P* means predictor. Under column Subtype, the notation *RV* means research variable and *CV* means control variable. The variable *Age* does not have a source because it is calculated based on the grant year of a patent using the equation: 2019-grant year +1. Under the column Source, the databases except Kogan are either obtained directly from the USPTO or supported by the USPTO (PatentsView); 'Kogan' is the source for patent value estimates in US dollars from Kogan et al. (2017).

3.4 Results and Discussion

3.4.1 Descriptive Analysis

First, I study how *Scope* has evolved. As shown in Figure 3.1, the trend in average *Scope* over the years of the patent grant between 2001 and 2014 is overall increasing. This finding makes us suspect whether the comparative patent scope measures based on claims such as the average number of independent claims (average claims count) or the average number of words in an independent claim (average claim length) have also increased during the same grant year range. I refer to Marco, Sarnoff et al. (2019) that the scope of granted patents based on these comparative scope measures is overall *decreasing* during the grant year range of 2001-2014;[9] the authors attribute the "stringency" of the patent examination process following the various patent quality improvement initiatives at the USPTO since 2004 as a possible reason for the overall decrease in these scope measures over time.[10]

My observation of an opposing trend in average *Scope* compared to that in the comparative scope measures indicates that innovators regularly use the open-ended scope terms in claims to broaden the patent scope along the claim interpretation dimension; incidentally, such a use mitigates the effect of reduction in the overall patent scope due to a reduction in the scope based on the comparative scope measures. I also find that the trend in average *Scope* is not technology-specific; refer to appendix Figure B1 for the similarity in the trends across the different NBER technology categories.

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[9] We independently generate these charts (unreported) for our sample and concur with Marco, Sarnoff et al. (2019)

[10] An observation of the opposite nature of the trends in average *Scope* and average claim length could be misleading as the count of words in an independent claim is inclusive of the count of the open-ended scope terms. We find that even after removing the open-ended scope terms from the independent claims in our sample, the trend in scope based on the corrected average claim length remains unchanged.

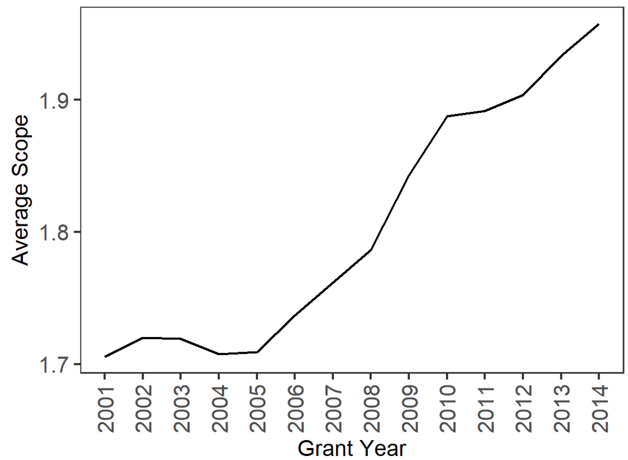

Figure 3.1. Trend in *Scope*
Notes. This figure presents the yearly average *Scope* for patents during the grant years 2001-2014. The number of observations equals 2,368,474.

I further reflect from Figure 3.1 that the open-ended scope terms in the independent claims of a patent at grant can originate at two stages: the patent application stage when the terms are strategically included by the innovator based on an expectation of a broad scope for the patent at issuance and the examiner leaves them untouched if their inclusion is self-justified (satisfies the patentability requirements) or the patent examination stage when the terms are tactically introduced by the innovator to broaden the claim scope along the claim interpretation dimension whilst the examiner reduces the overall scope of the patent by reducing the claims count and increasing the claim length.

Marco, Sarnoff et al. (2019) inform that examiner "stringency" typically reduces the scope of a granted patent (based on each of the comparative scope measures I consider) compared to its pre-grant publication and this reduction is sustained through the grant years of 2001 to 2014. I check whether a similar pattern is also seen with *Scope* in a smaller subset of 1.47 million patents in my research sample whose pre-grant publication claim information is available. The results are shown in Figure 3.2 from which it's evident that the average *Scope* of a granted patent (solid line) invariably *exceeds* that of its pre-grant publication (dashed line) in each year of the study. These findings strengthen my insights that innovators use the open-ended scope terms in the claims both strategically and tactically to broaden the overall scope of the patents at issuance. My contrasting finding also contributes to the patent quality debate that the patent offices have been criticized to issue too many patents of “low quality” (Lemley & Sampat, 2008), which is often linked to the *overly* broad scope of the issued patents among other factors (see Marco et al., 2019; Sterckx, 2006). I believe that since the USPTO explicitly lays down rules on how to interpret the scope-related terms in the claims, the presence of these terms in patents justifies the patentability standards. My findings are suggestive of systemic issues in legally authorizing patents with an overly broad scope as suspected by Marco Sarnoff. et al. (2019).

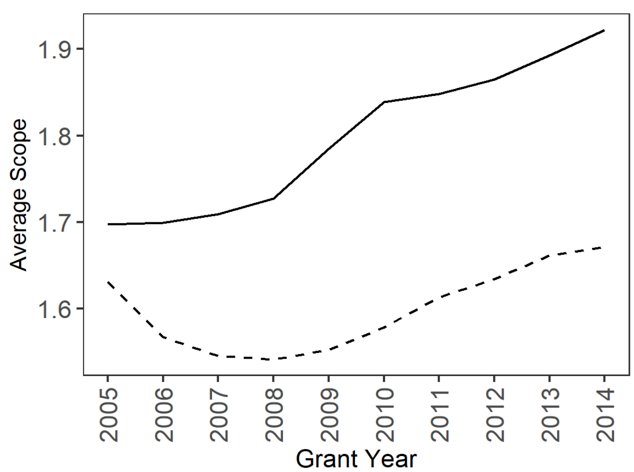

Figure 3.2. Comparative Trend in *Scope* for Granted Patents and Pre-grant Publications
Notes. This figure presents the yearly average *Scope* during the grant years 2005-2014 for a granted patent (solid line) and its pre-grant publication (dashed line). The number of observations equals 1,477,354.

In appendix B, I present some examples of patents from the sample where I find evidence that innovators introduce the open-ended scope terms in the independent claims during patent examination.[11]

In Table 3.2, I provide the summary statistics for the discrete and continuous numerical variables in my research sample. I see from Table 3.2 that each of the response variables (denoted by *R*) and predictors (denoted by *P*) have a right-skewed distribution. For my nominal response variables *Litigation*, *Reassign,* and *Security,* the probabilities of occurrence of the corresponding events in the sample are 0.79 percent, 9.2 percent, and 0.72 percent respectively. I then check the sub-category-wise proportions of patents for each of my nominal control variables *Technology, Origin*, *Assignee,* and *Entity*. Among the NBER technology categories for *Technology*, computers & telecommunication is the dominant with 34.1 percent of patents followed by electronics & electrical (23.9%), mechanical (12.6%), chemical (10.3%), drugs & medical (9.5%), and others (9.6%). For *Origin*, patents originating from non-provisional applications constitute 52.2 percent, those from PCT applications filed at the national stage constitute 12.5 percent, those from provisional applications and CAP each account for 11.9 percent, those from DIV constitute 7.5 percent, and those from CIP account for 4 percent of the patents in the research sample. For *Assignee,* corporate innovators constitute 94.2 percent of the sample and the rest are academics. For *Entity*, 86 percent of patents are filed by undiscounted entities and the rest by discounted (small or micro) ones.

[11] To remove the effect of averaging among the independent claims, we identify exemplary patents that have just one independent claim in both the application and the grant stage and ensure, based on the claim language, that these claims cover the same inventive aspect (as an independent claim in itself can be of different types such as a product or a process).

Table 3.2. Summary Statistics

Type	*N*	Variable	Mean	Median	SD	Min	Max
R	2,368,474	*Self-citations*	7.48	1	32.31	0	3412
R	992,284	*Value*	10.20	3.05	28.52	0.002	2663.73
P	2,368,474	*Scope*	1.83	1.5	1.29	0	114.75
P	2,368,474	*Claims Count*	2.84	2	2.17	1	248
P	2,368,474	*Claim Length*	173.36	154	106.62	1	12626
P	2,368,474	*Patent Classes*	1.74	1	1.15	1	31
P	2,368,474	*Cited Patents*	28.34	13	70.55	0	7783
P	2,368,474	*Inventors*	2.68	2	1.87	1	435
P	2,368,474	*Family*	4.12	3	4.13	1	58
P	2,368,474	*Age*	11.39	11	4.10	6	19

Notes. This table presents the summary statistics of the discrete and continuous numerical variables used in the study. *Value* is measured in 1982 (million) dollars. Under column Type, the notation *R* means response variable, and *P* means predictor. Refer to section 3.3.2 for the definitions of the variables. *N*: Sample size; SD: standard deviation; Min: minimum; Max: maximum.

Next, I check for multicollinearity among the discrete and continuous variables in the research sample based on the measures of pair-wise (Pearson's) correlations among them. The resulting correlation matrix is presented in Table 3.3. I use an absolute cut-off point of 0.3 as a heuristic to flag the correlations (see Kalnins, 2018) that may introduce substantial errors in my regression estimations due to multicollinearity. As seen in Table 3.3, my data has no such flags that merit attention.

Table 3.3. Correlation Matrix

	1	2	3	4	5	6	7	8
1. *Scope*	1							
2. *Claims Count*	-0.05	1						
3. *Claim Length*	0.26	-0.05	1					
4. *Patent Classes*	-0.02	0.02	-0.06	1				
5. *Cited Patents*	0.05	0.04	0.02	0.04	1			
6. *Inventors*	0.02	0	0.01	0.06	0.08	1		
7. *Family*	0	-0.03	-0.02	0.24	0.15	0.15	1	
8. *Age*	-0.07	0.11	-0.13	0.14	-0.12	-0.06	0.04	1

Notes. This table presents the correlation matrix for the discrete and continuous numerical (independent) variables in the research sample. The number of observations equals 2,368,474. The figures are pair-wise Pearson's correlation coefficients. Refer to section 3.3.2 for the definitions of the variables.

3.4.2 Regression Models

I first select the type of regression model to test the relationship between patent scope and patent value. Referring to the summary statistics in Table 3.2, I see that for the count variable *Self-citations*, the variance (square of SD) is disproportionately larger than the mean, indicating that the citation counts are over-dispersed; we, therefore, use negative binomial regression as the appropriate model (see Nemet & Johnson, 2012) for *Self-citations*. I use binomial logistic regression to model the binary outcomes *Litigation, Reassign*, and *Security,* and OLS regression to model the continuous response variable *Value*. As *Value* is right-skewed in distribution, I use its natural logarithm in the OLS model. The regression results are presented in Table 3.4 in which the results for *Self-citations* are presented in column (1), that for *Value* (natural logarithm) in column (2), and that for *Litigation*, *Reassign,* and *Security* in columns (3), (4), and (5) respectively.

Table 3.4. Patent Scope and Patent Value

Dependent variable	*Self-citations*	ln*Value*	*Litigation*	*Reassign*	*Security*
	(1)	(2)	(3)	(4)	(5)
Scope	0.0685***	0.0813***	0.0443***	0.0180***	0.0369***
	(9.00)	(4.26)	(5.33)	(3.34)	(5.81)
Claims Count	0.0601***	0.0480***	0.0702***	0.0191***	0.0320***
	(17.50)	(3.19)	(18.01)	(4.66)	(8.10)
Claim Length	-0.0001	-0.0020***	-0.0007***	-0.0006***	0.0001
	(-1.06)	(-4.61)	(-3.46)	(-6.68)	(1.18)
Patent Classes	-0.0184*	-0.1635***	0.0138	0.0221***	-0.0001
	(-1.89)	(-6.7)	(1.35)	(3.03)	(-0.01)
Gt Year FE	Y	Y	Y	Y	Y
Age	Y		Y	Y	Y
Other controls	Y	Y	Y	Y	Y
McFadden R^2	.0278		.1080	.0351	.061
Adjusted R^2		.1117			
Observations	2,368,474	992,284	2,368,474	2,230,993	2,368,474

Notes. This table presents the results of the regression of the private value of a patent on *Scope* and several patent quality indicators. The response variable ln*Value* is the natural logarithm of *Value*. Other controls include the following control variables: *Cited Patents* (the count of cited patents), *Inventors* (count of the number of inventors), *Family* (the number of countries in which invention protection was sought), *Technology* (the standard NBER technology class of a patent), *Origin* (the patent's relationship to its parent application at the USPTO), *Entity* (the size of the filing agent), and *Assignee* (the corporate or academic nature of the filing agent). Figures in parenthesis are t-statistics for OLS regression in column (2) and z-statistics for negative binomial regression in column (1) and binomial logistic regressions in columns (3) through (5) based on robust standard errors clustered at the assignee level. FE: Fixed effect; Y: yes. The sample size in column (2) is smaller compared to that in the other columns because the former contains data on the U.S. dollar value of patents which are available for patents assigned to publicly listed firms alone. The larger samples used for the other models contain data on patents assigned not only to publicly listed firms but also to academic assignees and privately held corporate firms. I use R programming package *glm* for negative binomial and logistic regressions and *lm* for OLS regression.
Significance level notations:
* $p < .10$, ** $p < .05$, *** $p < .01$

Each of the regressions except *Value* includes all the control variables discussed in section 3.3.2; the regression for *Value,* as it's measured at patent grant, doesn't require *Age* as a control. In Table

3.4, for logit models 3, 4 and 5, the binary response is transformed internally by the regression algorithm into log odds ratio, which is the logarithm of odds ratio — the ratio of the probability of success of an event to the probability of failure of the event. Following Hoetker (2007), the logit coefficient (β) in the models is interpreted thus: a one-unit change in the predictor corresponds to a change in the odds of the response variable by a factor of exp(β), *ceteris paribus*; values of exp(β) *greater* than one *increases* the odds of the event occurring and values *less* than one *decreases* the odds. For negative binomial regression in model 1, following Long (1997), the coefficient (β) is interpreted thus: a one-unit change in the predictor corresponds to a change in the expected count of the response variable by a factor of exp(β), *ceteris paribus*. For log-linear regression in model 2, following Benoit (2011), the coefficient (β) is interpreted thus: a one-unit change in the predictor corresponds to a change in the expected value of the response variable by exp(β), or equivalently, by 100(exp(β) – 1) percent. For regression coefficients, I report robust standard errors clustered at the patent assignee level to account for potential correlations among the error terms for patents with the same assignee.

The analysis of the estimates of the coefficients in the regression models (Table 3.4) provides several insights. First, the association of *Scope* with the private value of patents is positive and highly significant (p-value < .01) across the models. This finding provides strong support for my hypothesis *H*. The estimated coefficients imply that, on average, *ceteris paribus*, for every additional open-ended scope term in an independent claim: the expected count of self-citations to a patent *increases* by a factor of 1.071, the expected U.S. dollar value of a patent at issuance (1982 million) *increases* by 8.5 percent, the odds of litigation of a patent *increases* by a factor of 1.045, the odds of reassignment of a patent to other firm *increases* by a factor of 1.018, and the odds of collateralization of a patent *increases* by a factor of 1.038.

Beyond statistical significance, the magnitude of the effect of the coefficients in the regression models is suggestive of the economic significance of *Scope*. Bessen (2008) discusses the concept of economic significance (on page 940) in his seminal paper on patent valuation; using Bessen as a guide, the economic significance of model findings can be explained. For example, referring to Table 3.2, the median value of patents (*Value*) in the sample is 3.05 million U.S. dollars (the median value is considered as typical of the sample because patent value is highly right-skewed in distribution). Based on the interpretation of the coefficient for *Scope* in the model for *Value* in column (2) of Table 3.4 as discussed above, *ceteris paribus*, every additional open-ended scope term in an independent claim is associated with an *increase* in the median value of the patent in the sample by 8.5 percent to 3.31 million U.S. dollars. This increase in the median value of patents of approximately 260,000 U.S. dollars is economically significant.

Second, the sign of the coefficient for *Scope* across the regression models in columns (1)-(5) remains unchanged; this is a strong indication that the positive association of *Scope* with patent value is reliable. I reflect on the reliability of the other scope measures included in the regressions *Claim Length, Claims Count,* and *Patent Classes* - and compare this with that of *Scope*. Whereas *Claim Length* is positive and insignificant (at 1 percent significance level) for *Security*, it is negative and significant (p-value < .01) for *Value*, *Litigation*, and *Reassign*, and negative and insignificant (at 1 percent significance level) for *Self-citations*. This observation of fluctuating sign of coefficients across models indicates the relationship of *Claim Length* with patent value is ambiguous. Based on Kuhn and Thompson (2019) and Marco, Sarnoff et al. (2019), a possible reason for this ambiguity is that claims in chemicals, drugs, and biotechnological domains are frequently written using a special Markush language (see Simmons, 1991); such claims when shortened make the claim *narrower* which upends the logic underpinning the construction of *Claim*

Length that shorter claims are broader in scope. My finding highlights a problem with the generalizability of results with *Claim Length* as a patent scope measure.

The relationship of *Claims Count* with patent value is stable across the regression models. *Claims Count* broadly captures the variance in patent scope along the legal exclusivity dimension (see Cotropia, 2005) and it's an established indicator of patent quality. I find that *Scope* is as reliable as *Claims Count* though the former captures the variation in patent scope along the almost orthogonal (correlation of -0.05, Table 3.4) claim interpretation dimension. The coefficient for *Patent Classes* also changes signs across regressions, which suggests that the relationship of *Patent Classes* with patent value is ambiguous, as also reported in prior empirical studies (see Kuhn & Thompson, 2019). Third, the effect of *Scope* on patent value is significantly larger than that of *Claims Count* in three of the five regression models (columns (1), (2), and (5)) and lower than that of the latter in the other two models. However, compared to the effect of *Claims Count*, the larger effect of *Scope* is observed at the cost of a larger associated robust standard error. Overall, the findings indicate that *Scope* has a higher power in explaining the variance in patent value compared to *Claims Count*.

It is evident from the regression studies that the main results are robust to the choice of the response variable — the indicator of private value of patents. I am careful not to make causal inferences in my study as both patent scope and patent value are likely to be driven by the quality of the underlying invention (see Dyer et al., 2020; Kuhn & Thompson, 2019). An instrumental variable may seem an appealing solution, as described by Kuhn and Thompson (2019), to mitigate this endogeneity concern. Kuhn and Thompson successfully use the examiner scope "toughness" as an instrument that's obtained based on the examiner's tendency to reduce the scope of a granted patent (*Claim Length*) compared to its pre-grant publication; an assumption that underpins the instrument's choice is that it's *independent* of the characteristics of the patent application. For *Scope*, as I find in section 3.4.1, patent examiners do not typically reduce the number of the open-ended scope terms in the independent claims of a pre-grant publication during the patent examination; also, patent applicants tend to successfully introduce such terms during the examination. These findings strongly suggest that an instrumental variable akin to that used by Kuhn and Thompson will be unsuitable for *Scope*.[12]

3.5 Conclusions

Patent scope is an important patent policy lever. An optimal patent scope is vital to incentivize innovators to seek patent protection on one hand and promote social welfare on the other through disclosure of the inventive knowledge and sustenance of a healthy, competitive environment through subsequent innovations that build or improvise on prior patents. Patents that serve these purposes have substantial positive effects on the economy. The concept of patent scope is difficult to measure because patent claims that provide direct information about the patent scope are hard to interpret. This difficulty limits the use of some of the commonly used scope measures in empirical studies such as the number of claims (historical) and the average number of words per independent claim (more recent).

I explicate a valid, stable, and complementary measure of patent scope based on claim interpretation. To obtain out scope measure, I identify specific scope-related terms in the patent claims that are traditionally used by patent practitioners and interpreted consistently by the patent

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[12] In unreported studies, we do find support to our argument that examiner scope toughness does not work as an instrument in our case. We also find from a regression model (adjusted $R^2 = 5.5\%$, F-statistic = 2,612) that this instrument is *not* independent of the characteristics of the pre-grant publication - *Claim Length*, *Claims Count*, *inventors, Cited Patents,* and *Family*; each of these regressors are individually significant ($p < .01$) even after using the categorical controls discussed in section 1.3.2 and clustering the robust standard errors at the assignee level.

office and the courts. Consistent with theoretical predictions, I find that my scope measure has a significant and positive association with multiple measures of patent value. The effect of my scope measure on patent value is also economically substantial. My findings suggest that innovators use the scope-related terms in patent claims strategically at the patent application stage and tactically during the patent examination; apparently, in both instances, the terms' inclusion is not objected to by the patent examiner. I surmise that the terms' inclusion in the claims is possibly justified based on the patentability standards set by the regulator. To innovators, the knowledge of my scope measure would enable a reasonably accurate assessment of patent value and facilitate well-founded decisions on patents such as the licensing, transfer, or collateralization of the patents in markets for technology. My research also contributes to the serious debate on patent quality. Often, poor-quality patents are associated with an overly broad scope. My findings are suggestive of systemic issues in legally authorizing patents with an overly broad scope.

My research has certain implications for policy and practice. First, my findings could impact the US patent examination process significantly as the patent examiners would now be advised to consider my scope measure in addition to the traditional claim counts and claim length as the measures of patent scope so that ultimately when the patent issues, it does so with an optimal scope that's based on equal consideration of each of the three scope measures and the merits of the case. I expect this consideration would intensify the patent examination process and could result in delayed patent grants (thereby negatively affecting innovation) and a more burdened US patent system in general (that's already stressed). Mitigation of this additional burden would require further policy intervention. Second, the trend analysis of my scope measure shows that the usage of scope-related terms in claims continues to increase. Whilst this development is beneficial to the inventors, scholars (Heger & Zaby, 2018; Merges & Nelson, 1994) posit that an overly broad scope for patents would harm society in the long term by curtailing future opportunities for technological advancement. This tension could result in more patent lawsuits and associated protracted battles that could limit potential invention (and investment) possibilities.

My work has a limitation. Though the open-ended scope terms used in my scope measure construction are officially recognized as transitional phrases in patent claims that connect the claim's preamble to its body, I find that these terms are also used regularly in the body of the claims. I suspect a better scope measure would place different weights on the open-ended scope terms in the independent claims. To get these weights, one needs to precisely identify the location of the scope terms as the transitional phrase or within the body of the claims. Though I expect this exercise to be computationally intensive and challenging, the resulting measure could have a higher power in explaining the variance in patent value. Nevertheless, my work continues the prior efforts by scholars in recognizing and identifying scope measures based on claim interpretation.

My study also illuminates some future research opportunities. An intriguing research angle worth exploring would be to understand how the other major patent offices of the world (Europe and Japan in particular) allow scope-related terms in the claims. It could be possible that the scope-related terms that I investigate in the context of US patents have an equivalent usage in non-English language patents. This inquiry would help to enhance the generalizability of my findings. Another appealing research opportunity would involve studying how the descriptive parts of patent disclosure support the claim scope. Specifically, if patents are overly broad, their scope is too broad compared to the scope of the disclosed invention. I believe, to the best of my knowledge, there is a virtual absence of literature on how to measure the scope of the disclosed invention. The pervasiveness of disclosure obligations for a patent and their conspicuous absence in economic and legal scholarship warrant further investigation (we second Holbrook, 2006). Through my current findings, I hope to stimulate more research into the important area of patent scope and its relation to innovation and the economy.

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Appendix B

Relevant sections in the U.S. patent statute that inform on patent scope

The following sections (quoted verbatim with emphasis added) under Manual of Patent Examining Procedure (MPEP) § 2111.03 are highly relevant to patent scope:

i. The transitional phrases “comprising”, “consisting essentially of” and “consisting of” *define the scope of a claim* with respect to what unrecited additional components or steps, if any, are excluded from the scope of the claim. The determination of what is or is not excluded by a transitional phrase must be made on a case-by-case basis in light of the facts of each case.

ii. The transitional term “comprising”, which is synonymous with “including,” “containing,” or “characterized by,” *is inclusive or open-ended* and does not exclude additional, unrecited elements or method steps.

iii. The transitional phrase “consisting of” *excludes* any element, step, or ingredient not specified in the claim. The transitional phrase “consisting essentially of” *limits the scope* of a claim to the specified materials or steps “and those that do not materially affect the basic and novel characteristic(s)” of the claimed invention.

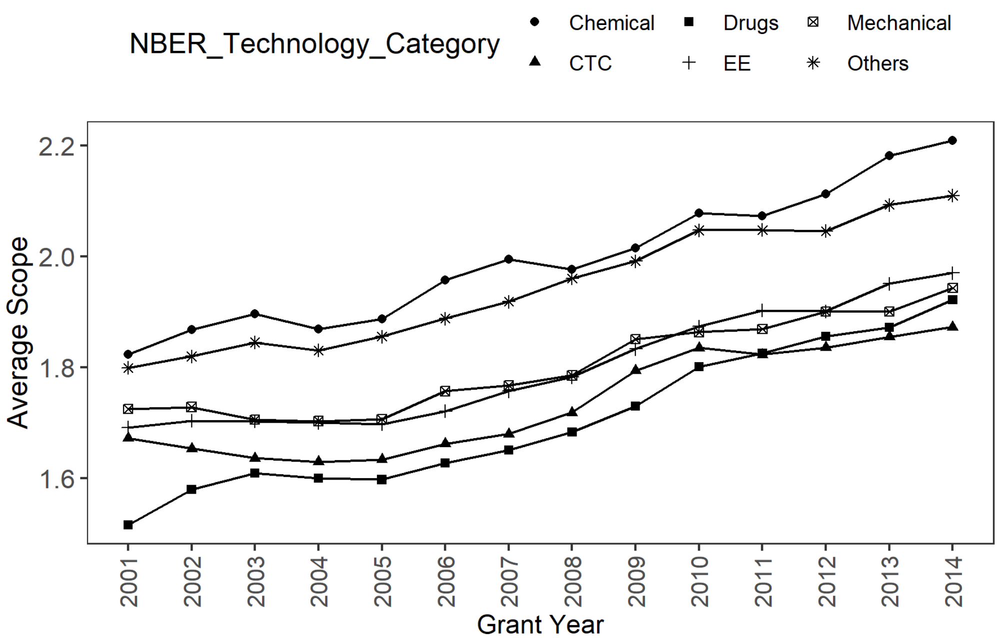

Figure B1. Trend in *Scope* by NBER Technology Category
Notes. This figure presents the yearly average *Scope* for patents during grant years 2001-2014 for the NBER technology categories of Chemicals, Drugs and Medical (Drugs), Mechanical, Computers and Communication (CTC), Electrical and Electronics (EE), Mechanical, and Others. The number of observations equals 2,368,474.

Comparison of claims of granted patent and its pre-grant publication.

Examples 1-4

Example 1. US7399610B2 assigned to Shimadzu Corp

Claim 1. A method for cell-free protein synthesis, said method **comprising**:
contacting a reaction solution **comprising** an insect cell extract solution and necessary components for protein synthesis with an external solution through a semipermeable membrane, wherein the reaction solution is subjected to translation to produce a protein, and
maintaining the production of said protein, while (a) supplying exogenous mRNA and (b) removing components from said reaction solution by passing said components through the semipermeable membrane into said external solution, said components **comprising** substances which inhibit protein synthesis and degradation products which form during protein synthesis,
wherein the insect cell extract solution is obtained by separating the insect cell extract from an insect cell, said insect cell extract **comprising** insect cell components essential for protein synthesis,
wherein the insect cell extract solution is an established culture cell derived from insects of Lepidoptera, Orthoptera, Diptera, Hymenoptera, Coleoptra, Neuroptra, Hemiptera,
wherein said components removed from the reaction solution comprise one or more compounds selected from the group consisting of adenosine diphosphate (ADP), adenosine monophosphate (AMP), gunanosine 5′-diphosphate (GDP), guanosine 5′-monophosphate (GMP), phosphates, pyrophosphates, and products which are degraded and formed during protein synthesis and
wherein the necessary components for protein synthesis comprise one or more compounds selected from the group consisting of potassium salt, magnesium salt, dithiothreitol, adenosine triphosphate, guanosine triphosphate, creatine phosphate, creatine kinase, amino acid, RNase inhibitor, tRNA, exogenous mRNA, buffer, and EGTA.
Pre-grant publication US20060084146A1 of US7399610B2

Claim 1. A method for cell-free protein synthesis using an extract derived from an insect cell, the method **comprising** removing a component which can pass through a semipermeable membrane through the semipermeable membrane while maintaining synthesis reaction, thereby to continuously synthesize a protein.

Example 2. US7005072B2 assigned to North Carolina State University

Claim 1. A method for removing phosphorus from a wastewater effluent stream **comprising** the steps of:

(a) introducing wastewater effluent **including** a phosphorous content to the bottom of a continuous crystallizer **comprising** a fluidized bed of struvite therein and a struvite crystal collection chamber therebeneath, said crystallizer being formed such that the cross sectional area thereof generally increases from a relatively smaller cross sectional area at the bottom thereof to a relatively larger cross sectional area at the top thereof;

(b) introducing an effective amount of ammonia to the wastewater effluent at the bottom of the crystallizer to elevate the wastewater stream effluent pH range a predetermined amount;

(c) introducing an effective amount of magnesium to the wastewater effluent at the bottom of the crystallizer;

(d) continuously passing the wastewater effluent **including** ammonia and magnesium upwardly through the fluidized bed of struvite to reduce the total phosphorus content of the wastewater effluent a predetermined amount;

(e) removing the treated wastewater effluent from the top of the crystallizer; and

(f) periodically removing struvite crystals that grow large enough to sink from the bottom of the crystallizer into the collection chamber.

Pre-grant publication US20060000782A1 of US7005072B2

Claim 1. A method for removing phosphorus from a wastewater effluent stream **comprising** the steps of:

(a) introducing wastewater effluent to the bottom of a continuous crystallizer **comprising** a fluidized bed of struvite therein and a struvite crystal collection chamber therebeneath, said crystallizer being formed such that the cross sectional area thereof generally increases from a relatively smaller cross sectional area at the bottom thereof to a relatively larger cross sectional area at the top thereof;

(b) introducing an effective amount of ammonia to the wastewater effluent at the bottom of the crystallizer to elevate the wastewater stream effluent pH range a predetermined amount;

(c) introducing an effective amount of magnesium to the wastewater effluent at the bottom of the crystallizer;
(d) continuously passing the composition-adjusted wastewater effluent upwardly through the fluidized bed of struvite to reduce the total phosphorus content of the wastewater effluent a predetermined amount;
(e) removing the treated wastewater effluent from the top of the crystallizer; and
(f) periodically removing struvite crystals that grow large enough to sink from the bottom of the crystallizer into the collection chamber.

Example 3. US6913288B2 assigned to Joyson Safety Systems Inc.

Claim 1. An apparatus **comprising** a load limiting device which serves as a connection between a vehicle safety restraint and an anchor point, the load limiting device **comprising** a housing and a deformable member, at east one of which is configured for connection to a vehicle safety restraint and the other of which is configured for connection to the anchor point, the housing and the deformable member being moveable relative to each other in a predetermined manner when force is applied to one or the other of the housing and the deformable member, and the housing having a hardened member which is harder than the deformable member, the hardened member positioned to engage and deform the deformable member as the deformable member moves relative to the housing; the housing **comprising** a pair of housing components which define an opening through which the deformable member is pulled and wherein the hardened member **comprising** a ball made of hardened steel that is (i) supported by the housing components, (ii) located in the opening in the housing and (iii) positioned to engage and deform the deformable member as the deformable member is being pulled through the opening in the housing; and the deformable member **comprising** a strip formed of mild steel and having a first portion configured for connection to a component of safety restraint system and a second portion having a stop; the strip having a central portion located between the first and second portions that is configured to be deformed in a predetermined manner when the strip is pulled through the housing and engaged by hardened member.

Pre-grant publication US20050012318A1 of US6913288

Claim 1. An apparatus **comprising** a load limiting device which serves as a connection between a vehicle safety restraint and an anchor point, the load limiting device **comprising** a housing and a deformable member, at least one of which is configured for connection to a vehicle safety restraint and the other of which is configured for connection to the anchor point, the housing and the deformable member being moveable relative to each other in a predetermined manner when force is applied to one or the other of the housing and the deformable member, and the housing having a hardened member which is harder than the deformable member, the hardened member positioned to engage and deform the deformable member as the deformable member moves relative to the housing.

Example 4. US7409276B2 assigned to UD Trucks Corp.

Claim 1. An electricity storage controller for a vehicle **comprising**:
a rotary electric machine serving as a prime mover of the vehicle;
an electricity storage device serving as a main power source of the rotary electric machine and **including** a power storage module which contains plural storage cells that are connected in series;
means for determining assigned voltages of the storage cells;
means for calculating an average value of the assigned voltages; and
means for equalizing the assigned voltages the storage cells based on the average value, the means for equalizing **including**:
a plurality of bypass circuits, which are normally open, and which are connected in parallel with respective ones of the storage cells;
means for setting a bypass reference voltage based on the average value of the assigned voltages of the storage cells; and
means for closing the bypass circuits of the storage cells if their assigned voltage exceeds the bypass reference voltage.

Pre-grant publication US20060080012A1 of US7409276B2

Claim 1. An electricity storage controller for vehicles **comprising**:
a rotary electric machine which constitutes a prime mover of a vehicle;

an electricity storage device serving as a main power source of the rotary electric machine and composed of a plurality of capacitor modules each of which contains plural capacitor cells;
means for calculating assigned voltages of each capacitor modules;
means for calculating an average value of the assigned voltages; and

means for equalizing the assigned voltages of each modules based on the average value.

4 Study 3

Too Good to Ignore for Innovators: Disclosure Quality of Patents and Private Value

Abstract

Patent disclosures facilitate the diffusion of the technical information embodied in innovations among the public. How does the quality of a patent disclosure benefit the disclosing innovator? I ground my research in one aspect of the disclosure theory of patents and test, for the first time, the effect of the quality of patent disclosures on their private value in the markets for technology and finance. By drawing upon related literature in business communication, accountancy, and finance, I measure the quality of patent disclosures as their ease of readability. My empirical findings are consistent with theoretical predictions. My research has implications for practice. *Ceteris paribus*, for patents assigned to publicly listed firms, an increase in the readability of patent disclosures by 10 percent corresponds to an increase in the dollar value of patents by 18 percent, and for patents assigned to firms, a similar increase in readability corresponds to an increase in the odds of reassignment of patents by a factor of 1.074. My findings suggest that it may be possible to remove poorly enabled patents from the system at source, which would improve the efficiency of the patent office.

Keywords: Disclosure theory, disclosure quality, patent value, readability, information asymmetry

4.1 Introduction

Industrial innovations contribute significantly to the accumulation of societal knowledge and are engines of macroeconomic growth (Aghion & Howitt, 1992). Two major theories of patents — the incentive theory and disclosure theory — explain the role of patents in the economy (Eisenberg, 1989; Mazzoleni & Nelson, 1998; Williams, 2017). The more familiar (and the more extensively studied) incentive theory posits that the prospect of a patent motivates R&D investments and promotes innovations.[1] According to the central tenet of the disclosure theory, patent disclosures facilitate the diffusion of the technical information underlying patented innovations among the public and help in stimulating research ideas externally.[2]

Empirical literature embedded in the disclosure theory of patents addresses three important aspects of disclosures — timing, accessibility, and "quality". Studies find that faster patent disclosures decrease duplicative research efforts by competitors (Lück et al., 2020) and increase follow-on innovation (Baruffaldi & Simeth, 2020; Hegde et al., 2018; Kim & Valentine, 2021; Okada & Nagaoka, 2020). The association between the accessibility of patent disclosures and subsequent (external) innovation is also positive (Büttner et al., 2022; Furman et al., 2021). Dyer, Glaeser, Lang, and Sprecher (2020) report a positive effect of the disclosure quality of patents on follow-on (external) innovation; within the nanotechnology field, Sun (2018) finds no significant association between the disclosure quality of patents and knowledge flows. Reitzig (2004a) studies the association of patent disclosure attributes with the likelihood of opposition to European patents. Niidome (2017) investigates the correlation between the length of disclosure in Japanese patents

[1] Though invention and innovation are technically different terms, for the sake of this study, they mean the same thing. The incentive theory of patents is also referred to as the reward theory.
[2] The disclosure theory of patents is also known as "contract theory" in literature, which is so named to highlight the role of patent disclosures as social contracts.

and patent validity outcomes. The survey findings by Oullette (2012) support the premise that patent disclosures have informational benefits to readers across a range of technologies.

Although patent disclosures enlarge the storehouse of knowledge and have the potential to benefit the public in different ways, they are often criticized as being incomplete, opaque, and ambiguous (for example, see Eisenberg, 1989; Seymore, 2010), which casts a shadow over their social value promise. It is also known that innovators disclose information less efficiently in patents primarily for the fear of knowledge spillover among rivals (Hughes & Pae, 2015). Though spillover is inevitable, what is not fully appreciated in the empirical literature is that patent disclosures can *benefit* the disclosing innovators in certain ways, which is the premise of one aspect of the disclosure theory of patents (Mazzoleni & Nelson, 1998) and the focus of my study. For example, Levin et al. (1987) inform that potential licensees learn about the opportunity to license through patent documents. Long (2002) and Anton and Yao (2003) posit that information disclosed in patents can convey positive signals about the firm and attract investment in financial markets. I expect that an evidence-based appreciation by innovators of such benefits can motivate them to address some of the issues associated with the poor quality of patent disclosures.

Three empirical papers are tangentially related to my study. Hegde and Luo (2018) find that faster patent disclosures increase the speed of licensing deals. Another study suggests that the presence of patent disclosures during negotiation in technology markets does not increase the chance of negotiation success (de Rassenfosse et al., 2016). Heely, Matusik, and Jain (2007) find that patents reduce information asymmetries in industries where the link between patents and inventive returns is transparent, which reduces the underpricing of initial public offerings. I differ from these studies as I focus on how the quality of patent disclosures would affect transactions in the markets for technology or finance; I seek to answer my research question: *for the holder of a patent, what is* *the effect of the quality of the patent disclosure on the appropriation of value from the patent in the markets for technology or finance?*

Technically, patent disclosures include claims and descriptive sections about the claimed inventions; however, consistent with the central role of disclosures in information dissemination, I consider the descriptive sections of patent disclosures to serve this purpose most efficiently (see Fromer, 2008). Accordingly, of concern to my study is the non-claim, full-text of patents. In my research setting, I first analyze the full text of a sample of over two million U.S. patents. I measure disclosure quality as the ease of *readability* of patents following Dyer et al. (2020). Consistent with my research hypotheses, I study two measures of appropriation of value from patents: estimates of patent value based on the stock market reactions to patent grants (Kogan et al., 2017) and the likelihood of ownership transfer (reassignment) of patents (Serrano, 2010). Second, to facilitate causal inference, I adopt an instrumental variable approach; I measure the variation in the propensities of patent examiners to reject patent applications that do not meet the disclosure requirements of patentability as an exogenous variable to instrument for the quality of patent disclosures.

I advance three main contributions. My study extends the empirical adequacy of the disclosure theory of patents to contexts where the quality of technical information in patent disclosures benefits the patent holders in the markets for technology or finance; I find strong support (to my knowledge, I am the first provider) for my hypotheses of a positive relationship between the quality of disclosures and private value of patents in these contexts. From a policy standpoint, my results suggest that enablement as a patent policy variable is beneficial to patent applicants in certain ways; an appreciation of this benefit should incentivize patent applicants to file patent disclosures of high quality, which would help in removing poor quality patents from the system at source and hence improve the efficiency and reputation of the patent office. This implication is important because the patent office is often criticized to issue too many patents of poor quality (see Lemley & Sampat, 2008).

My results also contribute to practice by informing on the substantivity of the association between disclosure quality and the private value of patents in the markets for technology or finance. Specifically, for patents owned by publicly listed firms, *ceteris paribus*, an *increase* in the readability of patent disclosures by 10 percent corresponds to an *increase* in the patent value at grant, which is estimated based on the reactions to patent grants by the firm's investors in the stock markets, by 18 percent, and for patents assigned to firms, a similar increase in readability corresponds to an *increase* in the likelihood of reassignment of the patents in the markets for technologies by 7.4 percent.

The rest of the paper is organized as follows. In section 4.2, I discuss the theory, concepts, and hypotheses that underpin my study. In section 4.3, I describe the data collection strategy, justify the choice of variables in my regression models, and explain the method to construct my research and instrumental variables. In section 4.4, I provide a descriptive summary of the data and present the results of single-stage regression models with my research variable and two-stage regression models with my instrumental variable. In section 4.5, I discuss the significant theoretical and practical implications, and in the concluding section, I discuss the limitations of the study and present opportunities for future research.

4.2 Concepts, Theory, and Hypotheses

I adopt the WTO (2021) expression (in Article 29) of enablement in patents — the extent to which an applicant for a patent discloses the invention in a manner that is sufficiently *clear* and complete for the invention to be practiced by a skilled artisan — as the definition for the quality of enablement.[3] As enablement is the only uniformly applicable disclosure requirement in patents across major geographies (see Ouellette, 2012), I consider disclosure quality as conceptually equivalent to the quality of enablement. Consistent with Seymore (2010) and Dyer et al. (2020), I associate the disclosure quality of patents with their ease of *readability*. I adapt the definition of readability from Loughran and McDonald (2014) as the ability of the reader of a patent disclosure to comprehend relevant information in the disclosure.

In a leading study, Levin et al. (1987) suggest a link between the quality of information disclosure and the private value of patents in technology markets by providing an example that potential licensees of a patent may learn about the opportunity to license through the "announcement" effect of patent disclosures. Mazzoleni and Nelson (1998) posit that in one version of the disclosure theory of patents, the information disclosed in a patent would benefit an innovator in certain ways, particularly when the innovator cannot exploit all the uses of the patented invention. In such cases, arguably, the extent to which the information disclosed in a patent can attract the attention of an external party, say in the technology markets where patents are licensed or reassigned, would determine the extent to which the innovator can appropriate value from the patent through such external means. Concurring with Mazzoleni et al. (1998), citing the famous Arrow's paradox (1962), Arora and Ceccagnoli (2006) suggest that the quality of information disclosed in a patent is a factor that determines the likelihood of licensing of a patent. Mazzoleni and Nelson inform that the Bayh-Dole Act (see Thursby & Thursby, 2003) has led universities to "advertise" their

[3] The enablement requirement is different from the "best mode" requirement in a patent disclosure (see WTO 2021). The latter requires a patent applicant to include the best-known method for carrying out the invention in the patent application. The best mode requirement is not a mandatory patentability requirement in many major geographies (see Oullette 2012).

inventions more actively through patents; the authors suggest that (at least in some instances) the *information* regarding both the *nature of the patented invention* and its *uses* would be beneficial to the potential users (or licensees) of the patent and provide this as a context for the disclosure theory of patents.

Agrawal, Cockburn, and Zhang (2015) inform that information asymmetry is a factor that imposes transaction costs and causes the failure of markets for ideas. Since information asymmetry and disclosure quality are inversely related (Brown & Hillegeist, 2007), in technology markets, a higher quality of information disclosure in patents would lower the information asymmetry between the trading partners. A reduced information asymmetry would then facilitate transactions in these markets to a greater extent, which would increase the value of the patent to the patentee. These arguments lead us to my first hypothesis:

> *Hypothesis 1 (H1): For a patentee, ceteris paribus, the higher the quality of disclosure in a patent, the greater the appropriation of value from the patent in the markets for technology*.

Notably, in a study of automotive transactions in Japan and the U.S., Dyer (1997) theorizes that the greater the degree of sharing of information between transactors, the lower the information asymmetries and the lower the transaction costs. My hypothesis transfers the setting of Dyer to technology markets where patents are traded; since patents embody legally imposed property rights, as Arrow (1962) suggests and Anton et al. (2003) articulate, innovators may be more willing to disclose information efficiently in patents without fearing misappropriation by rivals.

Long (2002) argues that a patent's private value may not *just* be determinable by the rents obtained from the commercial use of the patent in a product market. Innovators can also benefit through other means, for example, by publicizing the information about the invention in patents; this value corresponds to the non-product market value of patents. Long posits that the information disclosed in patents may signal to potential investors about the ingenuity or value of the patenting firm and enable them to make informed investment decisions. In a product-innovation setting, Anton et al. (2003) surmise that enabling patent disclosures can convey positive signals about the disclosing firm and attract investment in capital markets. Logically, the relationship between patent disclosure quality, information asymmetry, and reduced transaction costs in the technology markets that underpins hypothesis H1 can also be applied to financial markets. Accordingly, I state my second hypothesis.

> *Hypothesis 2 (H2): For a patentee, ceteris paribus, the higher the quality of disclosure in a patent, the greater the appropriation of value from the patent in the markets for finance.*

It is also noteworthy that the relationship between the quality of patent disclosure and the private value of patents in the markets for technology and finance emerges from the ex-ante theory of patent value (Perel, 2014). In my first study, I find that the patent quality dimension of *sufficiency of disclosure* (which is conceptually equivalent to disclosure quality) is underexplored in extant literature; in this respect, the current study tests this proposition of the ex-ante theory.

4.3 Research Strategy

4.3.1 Data Sources

I choose the most representative and widely studied patent office in the world — the United States Patent and Trademark Office (USPTO). Consistent with the literature in the field of innovation economics, I choose utility patents as the sample for my study and the unit of observation as well as the unit of analysis as a granted patent.[4] I obtain my data from three sources - the USPTO, Clarivate, and PatentsView. I use the following USPTO datasets to construct my research variable (disclosure quality) and obtain information on all my control variables (except the technology class of patents, see the next paragraph): (1) Patent Examination Research Dataset (Graham et al., 2015) containing the information on the examination of U.S. patents published through 2019; (2) Patent Claims Research Dataset (Marco et al., 2016) containing the information on the claims for U.S. patents granted during 1976–2014 and US applications published during 2001–2014; and (3) Patent Assignment Dataset (Marco et al., 2015) comprising information on patent reassignments recorded at the USPTO since 1970. PatentsView is a data visualization, bulk download, and analysis platform supported by the USPTO, which I primarily use to obtain the full text of patents. I use Clarivate to extract information on the "family" variable (see Martinez, 2011) for patents (see details later).

To construct my instrumental variable and obtain the technology classes of patents, I use the current release of the USPTO Office Action Research Dataset for Patents (in short, the office actions dataset) (Lu et al., 2017). This dataset consists of information from 4.4 million office actions mailed from 2008 to 2017 to the applicants of 2.2 million unique patent applications. There are two sets of samples in this study, one for single-stage regressions and the other for two-stage instrumental variable regressions. The use of two sets is an operational necessity because the data for single-stage regressions are available for patents in the grant year range of 2001-2014 (inclusive), whereas the data for two-stage instrumental variable regressions are available *only* for patents granted including and after 2008. The year 2001 is chosen as the first year of patent grant

[4] This selection criterion excludes plant and design patents. We also exclude reissue patents as they have the same full-text as the granted patents from which they originate, which avoids double counting.

for single-stage regressions as the information on the origination of patents (a key control variable *Origin* in the regression models) is not available before 2001 for this data. The year 2014 is chosen as the last year of patent grant for both the regressions because the control variable *Scope* is available only until 2014 for both data sets.

4.3.2 Response Variables

I choose two indicators of patent value as response variables to test my hypotheses. First, patent reassignment is an agreement that transfers all interests in a patent right from an existing owner to a recipient (Graham et al., 2018; Serrano, 2010). In the markets for technology, trade generates private and social gains by reallocating patent rights to firms that are better at using the patented invention (Marco, Scellato, Ughetto, & Caviggioli, 2017). As the information on reassignment is available for patents assigned to firms alone in my data source (Patent Assignment Dataset), I exclude patents categorized as academic from my samples (for method, see section 4.3.5 on control variables). I use *Reassign* as a binary variable that takes values of one or zero based on whether a patent is subject to a firm-to-firm reassignment or not. Second, I use the estimates of the U.S. dollar value of patents that are assigned to publicly listed firms, which I obtain from Kogan et al. (2017). These estimates are based on stock market reactions to news about patent grants. I use this estimate to proxy for a patentee's appropriation of patent value in the markets for finance. Accordingly, *Value* is the dollar estimate (in millions) of the real value (the nominal value deflated to 1982) of a patent.

4.3.3 Research Variable

Following Dyer et al., I measure the readability of patent disclosures based on their Gunning's Fog Index values (Gunning, 1952). This Index is often used to measure the readability of business-related communications (Clark, Kaminski, & Brown, 1990) and financial statements of firms (Loughran & McDonald, 2014). The measure is reliable and valid (Clark et al., 1990). Further, among the several readability measures in literature (see Hasan, 2020; Kaminski & Clark, 1987; Klare, 1974; Meade & Smith, 1991), the calculations for Fog Index are straightforward, and the measure is easily interpretable. The relationship between readability and Fog Index is negative; the *lower* the readability of a text, the *higher* its Fog Index (Loughran & McDonald, 2014).

Fog Index is the sum of two factors (see Loughran & McDonald, 2014) - average sentence length (words per sentence) and percentage of complex words (words with three or more syllables). The sum is multiplied by 0.4 to predict the grade level (number of years of education) of the reader. For example, a Fog Index of 16 implies that the text is easily readable by a person with 16 years of (or four years of college) education (see Kaminski & Clark, 1987). I use R programming language to calculate Fog Index *(Fog)* for my sample.[5] I use the non-claim, full-text of patents available from PatentsView for *Fog* calculations.[6] For my robustness analysis, I consider an alternative (and less frequently used) measure of readability, the Kincaid Index (*Kincaid*), obtained from the Flesch-Kincaid Formula, which also predicts the grade level of the reader (see Li, 2008).[7]

The algorithm used in R Console (the statistical environment used for data analysis) for the construction of *Fog* and *Kincaid* variable is summarized below.

1. Load data with information on the *full-text* description of patents granted in 2001 (source: PatentsView database) (R function: 'fread') (results in single observation per patent);

[5] We use quanteda library in R for calculating the readability measures.
[6] The full-text of patents from PatentsView consists of all the descriptive sections in a patent except the section on the background of the invention.
[7] Flesch-Kincaid Formula = 11.8 * (syllables per word) + 0.39 * (words per sentence) – 15.59

2. Obtain the measure of *Fog* as well as *Kincaid* for each patent in the data from step 2 (R function: 'textstat_readability', R package 'quanteda');
3. Repeat steps 1 through 3 for each year of patent grant from 2002 through 2014 and collate the full sample.

4.3.4 Instrumental Variable

It may not be possible to make causal inference based on the observed association between patent disclosure quality and patent value as the association may partly reflect the effect of *omitted* variables on the research and response variables (resulting in biased coefficient estimates), which is known as the endogeneity problem in econometrics (see Chenhall & Moers, 2007; Semadeni, Withers, & Trevis Certo, 2014). In practice, omitted variables are difficult to measure. Angrist & Krueger (2001) inform that one solution to the endogeneity problem is to identify an instrumental variable that is correlated with the research variable but unrelated to the response variable.

I adapt the method of Dyer et al. (2020) to tackle endogeneity in the relationship between patent disclosure quality and patent value. The authors use the variation in patent examiners' propensities to reject applications that do not meet the disclosure (particularly, enablement) requirement of patentability at the USPTO as an instrumental variable for the disclosure quality of patents. Empirical evidence supports the premise that the assignment of patent applications to examiners at the USPTO is plausibly random (Sampat & Williams, 2019), which renders this instrumental variable exogenous (that is, unrelated to patent value but related to disclosure quality) and hence facilitates causal inference.

I provide a primer on the examination process at the USPTO (see Sampat & Williams, 2019) to understand the random assignment of patent applications to examiners. For every incoming application, the USPTO assigns a unique number as well as patent class and patent sub-class codes depending on the type of technology embodied in the application. These class and sub-class codes determine the examination "Art Unit" for the application's review. Within each Art Unit, a supervisor assigns the application to an examiner, for example, based on the last digit of the application number (a mechanical scheme) or based on a "first-in-first-out" scheme wherein, when an examiner requests for an application, the person gets the earliest filed application from the relevant technology pool. Essentially, the assignment of applications to examiners is random conditional on the technology type and filing year of applications; I use these covariates as controls for the instrumental variable (see section 4.3.5 on control variables) in my regressions. Post-assignment, examiners review the applications in correspondence with the applicants. Multiple rounds of rejections of different types or for different claims are possible during the examination. Eventually, applications that pass the examination issue as granted patents.

During the review, an examiner checks the application for compliance with several requirements of patentability; of relevance to my study is the disclosure requirement under 35 U.S.C § 112(a), which mandates that disclosure be written in full, clear, concise, and exact terms to *enable* a skilled artisan to practice the invention (USPTO, 2019). I adapt the method of Dyer et al. (2020) and specify my instrumental variable - examiner disclosure strictness or *EDS* — as the propensity of an examiner to reject patent applications that do not meet the disclosure requirement of patentability under 35 U.S.C § 112(a). Using the office actions dataset, I measure *EDS* as the proportion of all applications handled by an examiner, excluding the focal patent, that the examiner rejected under 35 U.S.C § 112(a).[8] This exclusion criterion ensures that the focal patent does not

[8] For example, if an examiner handled 101 applications and rejected 67 of them under 35 U.S.C § 112(a), *EDS* for the examiner = (67-1) / (101-1) = 0.66. In calculating *EDS*, we consider that an application is rejected by an examiner

introduce bias in my findings (see Kuhn & Thompson, 2019). To avoid empirical complexity, my calculation for *EDS* is different from that by Dyer et al., who include (apparently, based on the definition of their variable) the total of all patent applications examined by all the examiners in the denominator.[9]

In calculating *EDS*, consistent with Dyer et al. (2020) and Sampat and Williams (2019), I exclude "continuing" patent applications such as continuation, continuation-in-part, and divisional applications. These patents (having the same assignee) share close technological linkages with their originating (or parent) applications, which may bias the results of my regressions.[10] Further, based on Dyer et al., I only include patents whose examiners have reviewed at least 50 applications in the office actions data so that I do not attribute low *EDS* (or high examination leniency) values to examiners' inexperience.

To explain the relationship between *EDS* and the disclosure quality of patents, consider the following simple comparison. Say, there are two examiners E_1 and E_2. *Excluding* each focal patent *issued* by E_1 and E_2 respectively, if n_1 patents were examined by E_1 and n_2 patents by E_2, and m_1 ($m_1 \leq n_1$) patents were rejected by E_1 and m_2 ($m_2 \leq n_2$) patents were rejected by E_2 for not satisfying the disclosure requirement of patentability under 35 U.S.C § 112(a), *EDS* for E_1 (say EDS_1), which is the same for all patents issued by E_1, is m_1/n_1 and *EDS* for E_2 (say EDS_2), which is the same for all patents issued by E_2, is m_2/n_2. Then, controlling for other factors that would affect *EDS* for an

under 35 U.S.C § 112(a) *only once* if it is rejected at least once in any of the multiple office actions recorded in the office actions dataset. This method avoids double counting.

[9] In unreported studies, we find the calculation based on Dyer et al. (2020) provides an instrument that is highly correlated with other control variables for this instrument (with multiple correlation coefficients greater than 0.3). This necessitates an extraction of dominant factors to mitigate the problem of multicollinearity (see Kalnins (2018)) prior to OLS regressions; we avoid this computational complexity in our empirical analysis.

[10] For example, an examiner handling these continuing "child" applications might be "influenced" by the events surrounding the examination of the parent applications of these child applications.

examiner, $EDS_1 > EDS_2$ would imply that each patent issued by E_1 would have a higher quality of disclosure compared to each patent issued by E_2. This means examiners who are *stricter* in rejecting patents for not satisfying the 112(a) criterion of patentability would *issue patents that have a higher disclosure quality* compared to examiners who are more *lenient* in assessing the same criterion who would *issue patents that have a lower disclosure quality*. Therefore, at the operational level, the higher the *EDS* the higher the readability of patent disclosure (or the lower the *Fog* value); as seen later in Table 4.5, this relationship holds (and is statistically significant).

4.3.5 Control Variables

Dyer et al. (2020) use the number of words in the written description of a patent (*Length*) and the number of figures in the disclosure (*Figures*) as indicators of fullness and "clarity and conciseness" of the patent disclosure respectively. However, Marco et al. (2019) inform that *Length* and *Figures* are indicators of the complexity of the patented technology; in my samples, as these two variables have a correlation greater than 0.3 (unreported), I use *Figures* to control for the complexity of the invention and drop *Length* to avoid multicollinearity issues in regressions (see Kalnins, 2018).[11]

Further, based on extant literature, I use the following control variables that may affect patent value: (a) the count of claims (*Claims*) as an indicator of the magnitude of the inventive step (de Rassenfosse & Jaffe, 2018), (b) the average number of words per independent claim (*Scope*) as an indicator of the scope of the invention (Marco et al., 2019), (c) the number of unique 4-digit international patent classification (IPC) technology classes assigned by the examiner (*IPC*) as an indicator of the technological breadth of the patent (Lerner, 1994), (d) the count of cited patents

[11] Dyer, Glaeser et al. (2020) also use Stanford Named Entity Recognizer (NER) to measure the "exactness" of patent disclosures. We do not have access to this variable for our samples.

(*Cites*) that captures the extent of patenting activity in a particular technical field (Harhoff & Reitzig, 2004), (e) the number of inventors (*Inventors*) in a patent that's a reflection of the diversity and size of the knowledge pool that could affect the patent's impact (Petruzzelli, Rotolo, et al., 2015), (f) the number of countries or geographies where the patent was applied for protection (*Family*) that's an indication of the commercial potential of the invention (Lanjouw et al., 1998),[12] and (g) the age of a patent (*Age*) that controls for the post-grant time-sensitivity of my response variable *Reassign.*

Taking a cue from Dyer et al. (2020), I include several non-35 U.S.C. § 112(a) rejections by an examiner as controls for *EDS*. Examiner novelty strictness of type A *(ENS_a),* type B *(ENS_b), or* type E *(ENS_e)* is the propensity of an examiner to reject patent applications that do not meet the novelty requirement of patentability under 35 U.S.C § 102(a), § 102(b), or § 102(e) respectively. Examiner non-obviousness strictness *(ENOS)* is the propensity of an examiner to reject applications that do not meet the non-obviousness requirement of patentability under 35 U.S.C § 103(a). Examiner objection strictness *(EOS)* is the propensity of an examiner to object to applications on "other" grounds. I use the office actions dataset to construct these control variables; refer to the definitions of these in appendix Table C1.[13]

[12] We exclude all PCT (WO) applications from *Family* and consider published and granted patents in any geography as a single family member, which avoids double counting. For example, a patent family could include a US granted patent (mandatory), US application, WO application, EP application, and EP granted patent. The *Family* value for this record is 1 of US + 1 of EP = 2.

[13] Other rejections are possible by an examiner including multiple subtypes under the subject matter eligibility requirement of 35 U.S.C § 101; we do not use these rejections as controls because the number of patents having each of these rejection subtypes range only between 0.0 and 1.2 percent of the office action dataset. To avoid serious multicollinearity problems in regressions (correlations ≥ 0.3), we also exclude three control variables corresponding to the rejection of patents due to double patenting, rejection of patents due to indefinite claims under 35 U.S.C § 112(b), and allowance of patents.

For single-stage and instrumental variable regressions, I use the following categorical (dummy) control variables. The USPTO technology center of patents (*Technology*) controls for the systematic variation in patent quality or value across eight broad technological categories. Refer to appendix Table C2 for the different types of technologies. The variable *Origin* identifies the type of parent application in my sample or the type of child application in my sample in relation to its parent (see Hegde et al., 2009); refer to appendix Table C3 for the different categories under *Origin*. I also use a patentee-level dummy variable to control for the variation in patent value at a more macro level such as the size of the filing entity (a small or micro entity that receives a filing fee discount at the USPTO, or a large entity that does not have this benefit) (*Entity*) (see Alcácer et al., 2009). I include fixed effects for patent grant year (*Grant Year*) and filing year (*Filing Year*) to control for the variation in patent disclosure quality or value due to events that may have occurred during the years of patent grant or filing as the case may be (see Nemet & Johnson, 2012).[14]

Since by design, the patents in my samples need to be assigned to firms, I identify the nature of the assignment of patents using a custom algorithm and exclude patents with academic assignees.[15] I merge the patents taken from multiple sources by patent number and clean the data to remove the records with missing or erroneous values. My final data has four samples: the first sample with

[14] For our samples for single-stage regressions, *Filing Year* range is 1945-2014, and for instrumental variable regressions, the corresponding range is 2007-2014. As *Filing Year* has a very broad range which would result in too many dummy variables in regressions, we recode it into a categorical variable with patents filed prior to and including 1997 as belonging to the pre-1997 category and the rest of the patents belonging to their actual filing year categories. A very long gap between the filing and grant years for some patents is due to secrecy agreements at the USPTO. For example, see US6761862 (in our sample), which was filed by U.S. Department of Energy in 1945 but granted only in 2004.

[15] This classification of an assignee into corporate or academic is based on a text-mining technique we implement in R to classify the names of assignees with terms such as university, institute, government, academic, hospital, college, school, or foundation as academic and the rest as corporate. This classification slots all the academic-corporate jointly assigned patents to the category of academic.

2,276,797 patents for single-stage regressions of *Reassign*; the second sample with 1,004,975 patents for single-stage regressions of *Value*; the third sample with 383,923 patents for two-stage instrumental variable regressions of *Reassign;* and the fourth sample with 144,282 patents for two-stage regressions of *Value*.

The composition of the sample in terms of research, response and control variables along with the source database for each variable is presented in Table 4.1. All the variables for each observation in the sample are linked by a corresponding common identifier — the patent number.

Table 4.1. Composition of the Sample and Source

Variable	Source	Type	Subtype
Reassign	Patent Assignment Dataset	*R*	-
Value	Kogan	*R*	-
Fog, Kincaid	PatentsView	*P*	*RV*
EDS	Office Action Research Dataset for Patents	*P*	*IV*
Claims	Patent Claims Research Dataset	*P*	*CV*
Scope	Patent Claims Research Dataset	*P*	*CV*
Figures	PatentsView	*P*	*CV*
IPC	Clarivate	*P*	*CV*
Cites	Clarivate	*P*	*CV*
Inventors	Clarivate	*P*	*CV*
Family	Clarivate	*P*	*CV*
ENS_a, ENS_b, ENS_e, EOS, ENOS	Office Action Research Dataset for Patents	*P*	*CV*
Technology	Patent Examination Research Dataset	*P*	*CV*
Origin, Entity, Assignee, Grant Year, Filing Year	Patent Examination Research Dataset	*P*	*CV*
Age	-	*P*	*CV*

Notes. This table presents the details of the variables in terms of their source, type, and subtype used in the study. The column Source provides information on the database from which each variable is obtained. Under column Type, the notation *R* means response variable and *P* means predictor. Under column Subtype, the notation *RV* means research variable, *CV* means control variable, and *IV* means instrumental variable. The variable *Age* does not have a source because it is calculated based on the grant year of a patent using the equation: 2019-grant year +1. Under the column Source, the databases except Kogan are either obtained directly from the USPTO or supported by the USPTO (PatentsView); 'Kogan' is the source for patent value estimates in US dollars from Kogan et al. (2017).

4.4 Results

4.4.1 Descriptive Summary

For patents in my samples for single-stage and two-stage regressions, the likelihood of reassignment (*Reassign*) is 9.2 percent and 7.5 percent respectively.[16] In Table 4.2, I provide the summary statistics for numerical variables in my samples. *Value* has a right-skewed distribution (the mean is greater than the median), which is consistent with the literature on patent value distribution (see Scherer, 1965). All the control variables (denoted by *C* in Table 4.2) also have right-skewed distributions.

It is evident from Table 4.2 that *EDS* for examiners varies widely from null to 99 percent.[17] In each of my four samples, the distributions of patents in *Technology* and *Origin* are shown in Appendix Tables C2 and C3 respectively. For regressions involving *Reassign*, the proportion of patents with undiscounted assignees (a category in *Entity*) is around 86 percent in each of the first and third samples, whereas the corresponding proportion of patents is around 99 percent in the other two samples. From Table 4.2, I see that the mean value of *Fog* for patents in my samples is approximately equal to 20, which indicates that the "average" patent in my data would be easily readable by a person who is into doctoral studies (with 18 years of education up to postgraduation and two years of studies thereafter). This finding concurs with that of Dyer et al. (2020) who report a mean Fog Index value of around 19 for their sample. The independent numerical variables in my regressions have absolute correlations less than 0.3 (see appendix tables C4 and C5); hence, multicollinearity is not a problem in my studies (see Kalnins, 2018).

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[16] The values for *Reassign* are significantly different in the two samples because the sample for two-stage regressions are right-truncated as the filing year range for patents in this sample is 2007-2014.
[17] There are 7,549 and 7,231 examiners in the third and fourth samples respectively.

Table 4.2. Summary Statistics

Type	*N*	Variable	Mean	Median	SD	Min	Max
D	1004975	*Value*	10.25	3.05	28.40	0.00	1712.58
R	2276797	*Fog*	19.75	19.40	4.86	3.59	3542.6
R	2276797	*Kincaid*	16.05	15.68	4.70	0.17	3450.52
C	2276797	*Figures*	12.58	8.00	18.4	0.00	7092.00
C	2276797	*Claims*	17.49	16.00	12.67	1.00	887.00
C	2276797	*Scope*	174.5	154.8	107.97	1.00	12626.00
C	2276797	*IPC*	1.74	1.00	1.14	1.00	31.00
C	2276797	*Cites*	28.77	13.00	71.46	0.00	7783.00
C	2276797	*Inventors*	2.67	2.00	1.88	1.00	435.00
C	2276797	*Family*	4.23	3.00	4.29	1.00	58.00
C	2276797	*Age*	11.4	11.00	4.09	6.00	19.00
D	144282	*Value*	7.10	2.68	15.53	0.01	476.94
R	383923	*Fog*	20.19	19.85	3.53	5.75	508.54
R	383923	*Kincaid*	16.44	16.08	3.39	2.88	492.02
C	383923	*Figures*	11.73	8.00	14.74	0.00	3712.00
C	383923	*Claims*	16.01	16.00	9.11	1.00	322.00
C	383923	*Scope*	187.48	168.5	107.74	1.00	14104.00
C	383923	*IPC*	1.43	1.00	0.84	1.00	16.00
C	383923	*Cites*	25.76	13.00	63.49	0.00	3313.00
C	383923	*Inventors*	2.73	2.00	1.85	1.00	29.00
C	383923	*Family*	3.68	3.00	3.40	1.00	52.00
C	383923	*Age*	7.23	7.00	1.16	6.00	12.00
IV	383923	*EDS*	0.12	0.07	0.14	0.00	0.99
IC	383923	*ENS_a*	0.09	0.08	0.06	0.00	0.56
IC	383923	*ENS_b*	0.44	0.45	0.16	0.00	0.94
IC	383923	*ENS_e*	0.11	0.09	0.09	0.00	0.67
IC	383923	*ENOS*	0.68	0.73	0.18	0.00	1.00
IC	383923	*EOS*	0.46	0.46	0.19	0.00	0.97

Notes: This table presents the summary statistics of the discrete and continuous numerical variables in the four samples of my study. Grey highlighted rows correspond to the third and fourth samples. Under Type, notations *D* stands for dependent variable, *R* for research variable, and *C* for control variable for patent value. Notation *IV* means instrumental variable and *IC* means control variable for *IV*. *N*: Sample size; SD: standard deviation; Min: minimum; Max: maximum. The minimum for *Value* is not exactly zero but only reflects the first two decimal places. For other variables, a minimum of zero is exactly zero.

4.4.2 Single-Stage Regressions

I use binomial logistic regression to model *Reassign* and OLS regression to model *Value*. All the numerical variables having a skewed distribution are log-transformed (after adding a one to those with zero values) to satisfy the normality assumption of linear regressions. I present the regression results in Table 4.3; the results for *Reassign* are shown in models 1 and 2 and those for *Value* in models 3 and 4.

For logit models 1 and 2, the response — the incidence of reassignment, which is a binary variable — is transformed internally by the regression algorithm into log odds ratio, which is the logarithm of odds ratio — the ratio of the probability of success of an event to the probability of failure of the event. Following Hoetker (2007) and Benoit (2011), since the predictors in the logit models are log-transformed, the logit coefficient (β) can be interpreted thus: a δ percent change in the predictor corresponds to a change in the odds of the response variable by a factor of $\exp(\gamma\beta)$, *ceteris paribus*, where $\gamma = \log([100 + \delta]/100)$; values of $\exp(\gamma\beta)$ *greater* than one *increases* the odds of the event occurring and values *less* than one *decreases* the odds. For independent numerical variables in the linear log-log models 3 and 4, following Benoit (2011), each coefficient can be interpreted as elasticity — the percentage change in the response variable for a percentage change in a predictor, *ceteris paribus*; the coefficient (β) can interpreted thus: *ceteris paribus,* to get the percent change in the response variable for a δ percent change in the predictor, calculate $100(\exp(\gamma\beta) - 1)$, where $\gamma = \log([100 + \delta]/100)$. I report heteroskedastic robust standard errors for regression coefficients.

Table 4.3. Results of Single-Stage Regressions

Variables	*Reassign* Model 1	*Reassign* Model 2	log(*Value*) Model 3	log(*Value*) Model 4
log(*Fog)*	-0.75*** (0.02)	-	-1.74*** (0.02)	-
log(*Kincaid)*	-	-0.68*** (0.01)	-	-1.69*** (0.02)
log(*Claims*)	0.18*** (0.00)	0.18*** (0.00)	0.64*** (0.00)	0.64*** (0.00)
log(1 + *Figures*)	-0.03*** (0.00)	-0.03*** (0.00)	-0.55*** (0.00)	-0.55*** (0.00)
log(*Scope*)	-0.10*** (0.00)	-0.09*** (0.00)	-0.31*** (0.00)	-0.30*** (0.00)
log(*IPC*)	0.02*** (0.00)	0.02*** (0.00)	-0.35*** (0.00)	-0.35*** (0.00)
log(1 + *Cites*)	0.09*** (0.00)	0.09*** (0.00)	0.19*** (0.00)	0.19*** (0.00)
log(*Inventors*)	0.20*** (0.00)	0.20*** (0.00)	0.20*** (0.00)	0.20*** (0.00)
log(*Family*)	0.02*** (0.00)	0.02*** (0.00)	-	-
log(*Age*)	-1.07*** (0.02)	-1.08*** (0.02)	-	-
Constant	4.20*** (0.08)	3.83*** (0.08)	7.96*** (0.06)	7.37*** (0.05)
Grant Year	Yes	Yes	Yes	Yes
Filing Year	Yes	Yes	Yes	Yes
Technology	Yes	Yes	Yes	Yes
Entity	Yes	Yes	-	-
Origin	Yes	Yes	Yes	Yes
McFadden R^2	0.04	0.04	-	-
Adjusted R^2	-	-	0.21	0.22
Observations	2,276,797	2,276,797	1,004,975	1,004,975

Notes: Figures in parenthesis are heteroskedastic robust standard errors. I do not include *Family* in models 3 and 4 as information about this variable is available only as of 2019 and not as of the year of a patent's grant. *Age* is not relevant for models 3 and 4. I do not include *Entity* in models 3 and 4 as the variable has a dominant share of patents (> 98%) assigned to undiscounted entities. I use R programming language functions 'glm' for logistic and 'lm' for OLS regressions (both from 'stats' package).

* $p < .10$, ** $p < .05$, *** $p < .01$

In Table 4.3 (and hereafter), since *Fog* is my research variable of interest, I prefer models with this variable to explain my findings. Since *Fog* and readability are inversely related, I find preliminary support for my hypotheses H1 and H2 as the coefficient for log(*Fog*) is negative in model 1 (β = -0.75, *p*-value < .01) and model 3 (β = -1.74, *p*-value < .01). Therefore, my results are strongly indicative that *ceteris paribus*, the higher the disclosure quality of a patent, the higher the appropriation of value from the patent for a firm in the markets for technology (H1) or the markets for finance (H2).

Following the rules for interpretation explained earlier, based on the coefficient for log(*Fog*) from model 1, *ceteris paribus*, an *increase* in the readability of a patent by 10 percent is associated with an *increase* in the odds of reassignment of the patent by a factor of 1.074. Similarly, from model 3, *ceteris paribus*, an increase in the readability of a patent by 10 percent is associated with an increase in the dollar value of the patent at grant by 18 percent. I further reflect on the results in Table 4.3 to explain several findings. First, since the coefficients for *Fog* and *Kincaid* in the models for *Reassign* as well as *Value* are of comparable magnitudes and have the same sign, the results from my single-stage regressions appear to be robust to the change in the measurement of readability of patents. While these results are encouraging, they open promising avenues for further research; I discuss this implication in the concluding section.

Second, the association between readability and private value of patents is not only statistically significant but also economically significant. Using Bessen (2008), who discusses the concept of economic significance (on page 940) in his seminal paper on patent valuation, the economic significance of the model findings can be explained. For example, referring to Table 4.2, the median value of patents (*Value*) in the sample is 3.05 million U.S. dollars (the median value is considered as typical of the sample because patent value is highly right-skewed in distribution).

Based on the interpretation of the coefficient for *Fog* in the model for *Value* in model 3 of Table 4.3 as discussed above, *ceteris paribus*, a 10 percent *increase* in the readability of a patent is associated with an *increase* in the median value of the patent in the sample by 18 percent to 3.6 million U.S. dollars. This increase in the median value of a patent of approximately 550,000 U.S. dollars is economically significant. Conceptually, as readability and *Fog* share a negative relationship, a 10 percent *increase* in the readability of the median patent in the sample is equivalent to a *decrease* in the *Fog* value of the patent from 19.40 to 17.46.

Third, I see that two of the most reliable and established patent value indicators (see Sampat & Williams, 2019) that I use as controls — *Claims* and *Family* — have an expected positive association with patent value. Also, the sign of the coefficient for *Scope*, which is a recent addition to empirical literature (Kuhn & Thompson, 2019; Marco et al., 2019), is negative (as expected). These findings (related to controls) enhance the reliability of my regression models. I will tackle endogeneity in my models in the next section.

4.4.3 Two-Stage Regressions

Before studying two-stage regressions, in the spirit of Sampat et al. (2019), I investigate if my instrumental variable (*EDS*) is a valid exogenous regressor. This means *EDS* can *only* affect the value of a patent through the patent's disclosure quality. To test this validity, I first regress *Value* on the *control* variables (variable denoted as *C* in Table 4.2 except *Age* which is not relevant for regressions of *Value* as the latter is an estimate of value close to granting of a patent). I present the results of this regression in model 3 in Table 4.4. Next, I obtain the predicted measures of *Value* from model 3 and regress this variable (*Predicted Value*) on *EDS* along with the control variables for *EDS* (*IC* in Table 4.2) and other covariates that may affect *EDS* such as *Filing Year, Grant*

Year, and *Technology*. The results of this regression are shown in model 4 in Table 4.4; the coefficient for log-transformed *EDS* (0.05) is statistically significant (*p*-value < .1) but economically non-substantive — a 10 percent increase in *EDS* corresponds to a meager 0.5 percent increase in *Value*. For all practical purposes, as Sampat & Williams suggest, I can ignore this correlation and consider *EDS* to be exogenous.

In the *first* stage of my two-stage regressions, I regress *Fog* on *EDS* along with all the control variables for *EDS* as well as patent value. In Table 4.5, I document the results in model 5 for *Reassign* and model 7 for *Value*. In the *second* stage, following Terza, Basu, and Rathouz (2008), I adopt two different methods for regressing *Value* and *Reassign*. For the second stage OLS estimation of *Value*, I include the *predicted* measures of the endogenous variable (*Fog*) from the first stage along with all the control variables from the first stage. For the second stage maximum likelihood estimation (MLE) of *Reassign*, I include the *residuals* from the regressions in the first stage in addition to the *actual* measures of *Fog* along with all the controls from the first stage.[18] While this OLS estimation method is well known, Terza et al. inform that the unique method for MLE estimation helps in obtaining a consistent estimate of the coefficient for *EDS*. I present the results of the second stage regression for *Reassign* in model 6 and that for *Value* in model 8 in Table 4.5. The high values of the *F*-statistic in the first stage regressions (650 for model 5 ad 291 for model 7) indicate that my instrumental variable passes the test for weak instruments (the minimum value is 10, see Stock & Yogo, 2002). For our two-stage regressions, Wu-Hausman's test for endogeneity (Hausman, 1978; Nakamura & Nakamura, 1998) rejects the null hypothesis (*p*-value < .05) that *Fog* is an exogenous variable.

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[18] Since *Age* is not used (not relevant) in the first stage regression for *Reassign*, we do not include it in the second stage.

Table 4.4. Results of Instrument Validity Regressions

Variables	**log(*Value*)**	***Predicted Value***
	Model 3	**Model 4**
log(1 + *EDS*)	-	0.05* (0.03)
Claims	0.05*** (0.00)	-
log(1 + *Figures*)	-0.65*** (0.01)	-
log(*Scope*)	-0.35*** (0.01)	-
log(*IPC*)	-0.26*** (0.01)	-
log(1 + *Cites*)	0.27*** (0.01)	-
log(*Inventors*)	0.29*** (0.01)	-
ENS_a	-	-0.29*** (0.04)
ENS_b	-	-0.37*** (0.00)
ENS_e	-	0.59*** (0.00)
log(1 + *ENOS*)	-	-0.64*** (0.00)
EOS	-	0.03** (0.00)
Constant	1.59*** (0.1)	0.32*** (0.04)
Origin	Yes	-
Filing Year	Yes	Yes
Grant Year	Yes	Yes
Technology	Yes	Yes
Adjusted R^2	0.27	0.34
Observations	144,282	144,282

Notes: Figures in parenthesis are heteroskedastic robust standard errors. *Predicted Value* in model 4 is the variable for predicted measures of log(*Value*) from model 3. I use R programming language function ‘lm’ for OLS regressions (from ‘stats’ package).

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 4.5. Results of Two-Stage Regressions involving *Fog*

Variables	log(*Fog*) Model 5 (Stage 1)	*Reassign* Model 6 (Stage 2)	log(*Fog*) Model 7 (Stage 1)	log(*Value*) Model 8 (Stage 2)
log(1 + *EDS*)	-0.04*** (0.00)	-	-0.08*** (0.00)	-
Predict_Fog	-	-	-	-2.32*** (0.68)
log(*Fog*)	-	-5.43*** (1.52)	-	-
Residuals	-	4.86*** (1.52)	-	-
Claims	0.00*** (0.00)	0.01*** (0.00)	0.00*** (0.00)	0.05*** (0.00)
log(1 + *Figures*)	-0.02*** (0.00)	-0.1*** (0.03)	-0.01*** (0.00)	-0.68*** (0.01)
log(*Scope*)	0.04*** (0.00)	0.08 (0.06)	0.04*** (0.00)	-0.27*** (0.03)
log(*IPC*)	0.01*** (0.00)	0.06*** (0.02)	0.01*** (0.00)	-0.24*** (0.01)
log(1 + *Cites*)	0.00*** (0.00)	0.05*** (0.01)	0.00*** (0.00)	0.27*** (0.00)
log(*Inventors*)	0.01*** (0.00)	0.33*** (0.02)	0.01*** (0.00)	0.31*** (0.01)
log(*Family*)	0.01*** (0.00)	0.06*** (0.02)	-	-
ENS_a	-0.01 (0.00)	-0.15 (0.12)	0.02** (0.01)	-0.31*** (0.09)
ENS_b	-0.01*** (0.00)	-0.12** (0.05)	-0.01 (0.00)	-0.03 (0.04)
ENS_e	0.02*** (0.00)	0.67*** (0.09)	0.03*** (0.00)	0.49*** (0.06)
log(1 + *ENOS*)	0.01*** (0.00)	0.32*** (0.06)	0.04*** (0.00)	0.37*** (0.05)
EOS	-0.01*** (0.00)	-0.09** (0.04)	-0.02*** (0.00)	-0.17** (0.03)
Constant	2.84*** (0.09)	15.92***(4.44)	3.14*** (0.01)	8.71*** (2.16)
Filing Year	Yes	Yes	Yes	Yes
Grant Year	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes
McFadden R^2	-	0.05	-	0.05
Adjusted R^2	0.06	-	0.04	0.26
F-statistic	650	-	291	-
Observations	383,923	383,923	144,282	144,282

Notes: Figures in parenthesis are heteroskedastic robust standard errors. *Predict_ Fog* corresponds to predicted measures of log(*Fog*) from model 5. *Residuals* correspond to residuals from model 7. *Other controls*: *Technology*, *Entity*, *Origin* for models 5 and 6; *Technology*, *Origin* for models 7 and 8. I use R package 'ivreg' for estimating models 5 and 6 and to conduct the Wu-Hausman endogeneity test.
* $p < .10$, ** $p < .05$, *** $p < .01$

The results in Table 4.5 substantiate the preliminary results from my single-stage regressions in Table 4.3 and provide strong support for my hypotheses. Notably, I see that the effects of the coefficients for *Fog* after accounting for endogeneity are much higher compared to the corresponding effects in my single-stage regressions. From model 6, I interpret the coefficient of -5.43 for log(*Fog*) (*p*-value < .01) as *ceteris paribus*, an increase in the readability of a patent by 10 percent corresponds to an increase in the odds of reassignment of the patent by a factor of 1.68 (which supports my hypothesis H1). Similarly, from model 8, the coefficient of -2.32 for *Predict_Fog* (*p*-value < .01) means *ceteris paribus*, an increase in the readability of a patent by 10 percent corresponds to an increase in the dollar value of the patent at grant by 24.7 percent (which supports my hypothesis H2).

As part of robustness analysis, the results of two-stage regressions involving *Kincaid* as the alternative and less preferred endogenous regressor are documented in Table 4.6. As seen in the table, the sign and magnitude of the coefficients for *Kincaid* as well as *EDS* in both the first stage and second stage regressions are not very different from the corresponding regressions involving *Fog* in Table 4.5.

Table 4.6. Results of Two-Stage Regressions involving *Kincaid*

Variables	log(*Kincaid*)	*Reassign*	log(*Kincaid*)	log(*Value*)
	Model 9	**Model 10**	**Model 11**	**Model 12**
log(1 + *EDS*)	-0.06*** (0.00)	-	-0.11*** (0.01)	-
Predict_Kincaid	-	-	-	-1.79*** (0.53)
log(*Kincaid*)	-	-4.04*** (1.13)	-	-
Residuals	-	3.49*** (1.13)	-	-
Claims	0.00*** (0.00)	0.01*** (0.00)	0.00*** (0.00)	0.05*** (0.00)
log(1 + *Figures*)	-0.02*** (0.00)	-0.08*** (0.02)	-0.01*** (0.00)	-0.67*** (0.01)
log(*Scope*)	0.05*** (0.00)	0.07 (0.06)	0.05*** (0.00)	-0.27*** (0.03)
log(*IPC*)	0.01*** (0.00)	0.05*** (0.02)	0.01*** (0.00)	-0.24*** (0.01)
log(1 + *Cites*)	0.00*** (0.00)	0.05*** (0.01)	0.00*** (0.00)	0.27*** (0.01)
log(*Inventors*)	0.01*** (0.00)	0.32*** (0.01)	0.01*** (0.00)	0.31*** (0.01)
log(*Family*)	0.01*** (0.00)	0.06*** (0.02)	-	-
ENS_a	0.01 (0.00)	-0.09 (0.12)	0.02** (0.01)	-0.29*** (0.08)
ENS_b	-0.02*** (0.00)	-0.13** (0.05)	-0.01 (0.00)	-0.03 (0.04)
ENS_e	0.03*** (0.00)	0.67*** (0.09)	0.03*** (0.00)	0.50*** (0.06)
log(1 + *ENOS*)	0.01*** (0.00)	0.32*** (0.06)	0.04*** (0.00)	0.38*** (0.05)
EOS	-0.01*** (0.00)	-0.07** (0.04)	-0.02*** (0.00)	-0.17** (0.03)
Constant	2.56*** (0.11)	10.86*** (3.08)	2.95*** (0.01)	6.69*** (1.55)
Filing Year	Yes	Yes	Yes	Yes
Grant Year	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes
McFadden R^2	-	0.05	-	-
Adjusted R^2	0.06	-	0.05	0.27
Observations	383,923	383,923	144,282	144,282

Notes: Figures in parenthesis are heteroskedastic robust standard errors. *Predict_Kincaid* corresponds to predicted measures of log(*Kincaid*) from model 11. *Residuals* correspond to residuals from model 9. *Other controls*: *Technology*, *Entity*, *Origin* for models 9 and 10; *Technology*, *Origin* for models 11 and 12. We use R package ‘ivreg’ for estimating models 11 and 12.

* $p < .10$, ** $p < .05$, *** $p < .01$

4.5 Discussion

I extend the disclosure theory of patents from its most traditional context (see Mazzoleni & Nelson, 1998), which explains how the disclosure in a patent benefits the public through knowledge diffusion, to situations where the disclosing innovators can also benefit from the information disclosure in their patents. The benefits can accrue to innovators in different ways. In situations when the innovators cannot exploit all the potential uses of the patented inventions by themselves, the patents can be licensed or reassigned in technology markets that would extend the patents' (commercial) use and increase the private value of patents. In a different (though not mutually exclusive) context, Long (2002) explains that the information disclosed in patents can act as signals and attract investment in capital markets for a firm when the value proposition of its patents is not just the (commercial) use value. Building on the propositions of the disclosure theory of patents by Mazzoleni et al. (1998), the signaling theory of patents by Long, and the interplay between information quality, transaction cost, and information asymmetry by Dyer (1997) in automotive markets, I argue that the quality of information disclosed in patents (one aspect of enablement) would be a key factor that would (by reducing information asymmetry) make the patents more attractive to potential trading partners in the technology markets as well as investors in the capital markets.

Though the results are indicative of a strong and positive association between the disclosure quality and private value of patents in the markets for technology and finance, the causal inference based on the instrumental variable study is, at best, only preliminary and ungeneralizable. There are two principal reasons behind this caveat. First, the instrumental variable measures disclosure quality at the level of patent examiners, which leaves the plausibly significant patent-level variation in disclosure quality unmeasurable by the instrument. Second, Righi and Simcoe (2019) argue that the random matching of examiners to applications (which is a condition for the instrumental variable in our study to be exogenous) does not provide a general-purpose tool for causal inference about the patent system. Finally, the size effects of the instrumental variable in the two-stage regressions are much larger compared to those in the single-stage regressions. Again, this (plausibly) has to do with the instrument being measured at the level of the examiner. Though large size effect for an instrumental variable (in comparison to an endogenous regressor) is not uncommon in the general patent economics literature (see Galasso & Schankerman, 2014), due to the aforementioned issues with causal inference, the instrumental variable results are only supportive of the results from the single stage regressions.

An obvious practical implication of my work is to understand how a patenting innovator can use my findings to increase the readability of patent disclosures. I have articulated this aspect as the need to incentivize innovators to file patent applications that have high disclosure quality (meaning, well-enabled patents). As the Fog index is based on two factors, average sentence length and proportion of polysyllabic words, keeping sentences short and reducing the proportion of polysyllabic words per sentence should increase the readability of patent disclosures. As most of the patenting innovators would have dedicated intellectual property personnel, checking the Fog index of disclosures before patent filing, and accordingly increasing the readability of disclosures should not be a major concern. A Fog index of 16 means the patent disclosure is easily readable by a person having four years of college education. Since I see in my findings that the Fog measure, on average, for a patent in my samples is around 20, I believe there is a lot of scope for increasing the readability of disclosures.

The managerial and policy implications of my findings extend beyond patents at a microeconomic level to patent portfolios of firms. Firms are known to build patent portfolios with a dominant share of patents in the portfolios being held for *strategic* (non-commercial) purposes (Blind, Cremers, & Mueller, 2009; Parchomovsky & Wagner, 2005). Such firms can benefit tangibly to an extent if the disclosures in their patents are of reasonably good quality (presuming that, these patents being of less commercial importance to the innovators would be enabled at suboptimal levels). This is a certain win-win situation as the public would also benefit more from knowledge spillover from such disclosures. The cascading effect would also benefit the patent office because the examiners would then have to spend less time enforcing enablement requirements in patents and use the time saved in furthering the important role of the patent office in promoting the progress of science and useful arts.

4.6 Conclusions

My research has two methodological limitations. First, I use the Fog index to measure the quality of enabling disclosures. It is surely a reliable predictor of reading ease but not a seal of approval of enablement. Though the measure is used frequently in assessing the readability of business and finance documents, patents offer a different challenge in being (by design) technically sophisticated. I build on prior research and lay a solid ground for future research opportunities in this direction. A particularly promising research avenue would involve leveraging the tremendous progress made in natural language processing and text mining techniques in the past decade to develop a more precise measure for the quality of enablement in patents. Given the explosive growth in patenting across jurisdictions, this development would be most welcome as it would benefit the innovators, patent offices, and society at large.

Second, I am also cautious not to make sweeping generalizations from my causal inference. Though I exploit the plausibly random assignment of patent applications to examiners at the

USPTO to construct my instrumental variable, recent research by Righi and Simcoe (2019) has shown that the assumption of randomization may not hold in instances when the instrumental variable might still be correlated with unobserved characteristics of the patent application. Nevertheless, more robust quasi-experimental research designs in the future may contribute to theory, policy, and practice to a greater extent.

While I address one dimension of the disclosure quality of patents — clarity (see WTO, 2021), I also appreciate that for patents to be enabled fully, they also need to have a “complete” disclosure. There is a virtual absence of any method to measure the completeness of patent disclosures in extant literature but for the crude measure of the length of disclosures (typically measured by word counts) (for example, Dyer et al., 2020). I see this as an opportunity for an enterprising researcher to operationalize the completeness of patent disclosures, which would help in extending my findings. I also foresee that one can extend the generalizability of my results by investigating the relationship I study for patents in non-U.S. geographies (having non-English language) such as Europe, Japan, Korea, and China. I am unaware if readability measures exist for non-English text.

On a concluding note, my research makes a meaningful contribution to the important economic theory of patents – the disclosure theory. I believe that my research illuminates future research inquiries that could extend the empirical adequacy of the disclosure theory even further. While I have taken utmost care in presenting the findings in this paper, it goes without saying that I own all the errors in the paper.

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Appendix C

Table C1. Definitions of Controls for Instrumental Variable *EDS*

Variable	Notation	Definition
1. *Examiner Novelty Strictness Type A*	*ENS_a*	The proportion of all applications handled by an examiner, excluding the focal patent, that the examiner rejected under 35 U.S.C § 102(a)
2. *Examiner Novelty Strictness Type B*	*ENS_b*	The proportion of all applications handled by an examiner, excluding the focal patent, that the examiner rejected under 35 U.S.C § 102(b)
3. *Examiner Novelty Strictness Type E*	*ENS_e*	The proportion of all applications handled by an examiner, excluding the focal patent, that the examiner rejected under 35 U.S.C § 102(e)
4. *Examiner Non-obviousness Strictness*	*ENOS*	The proportion of all applications handled by an examiner, excluding the focal patent, that the examiner rejected under 35 U.S.C § 103(a)
5. *Examiner Objection Strictness*	*EOS*	The proportion of all applications handled by an examiner, excluding the focal patent, that the examiner objected to for minor informalities or patent rule violations

Table C2. Distribution of Patents for *Technology*

USPTO Technology class center	Technology class description	First sample (%)	Second sample (%)	Third sample (%)	Fourth sample (%)
1600	Biotechnology and Organic	8.29	5.60	6.68	4.26
1700	Chemical and Materials Engineering	12.69	10.08	11.81	7.77
2100	Computer Architecture Software and Information Security	8.31	13.33	7.27	12.20
2400	Computer Networks, Multiplex, Cable, and Cryptography/Security	4.80	6.86	8.16	12.96
2600	Communications	13.64	17.60	12.35	15.42
2800	Semiconductors, Electrical and Optical Systems, and Components	28.45	28.58	29.00	26.95
3600	Transportation, Electronic Commerce, Construction, Agriculture, Licensing, and Review	10.88	8.40	12.85	11.03
3700	Mechanical Engineering, Manufacturing, and Products	12.95	9.56	11.88	9.41

Notes: This table presents the distributional statistics of the control variable *Technology* (USPTO technology centers). Sample sizes: First sample = 2,276,797, Second sample = 1,004,975, Third sample = 409,577, Fourth sample = 144,282

Table C3. Distribution of Patents for *Origin*

Category of patent	First sample (%)	Second sample (%)	Third sample (%)	Fourth sample (%)
Non-provisional	51.72	57.40	59.32	66.70
PCT	13.01	8.36	23.23	15.45
Continuation	11.89	12.43	-	-
Provisional	11.83	10.80	17.45	17.85
Continuation-in-part	3.95	3.14	-	-
Divisional	7.60	7.87	-	-

Notes: This table presents the distributional statistics of the control variable *Origin*. Sample sizes: First sample = 2,276,797, Second sample = 1,004,975, Third sample = 409,577, Fourth sample = 144,282. PCT = patent cooperation treaty. Non-provisional, PCT, and Provisional are categories of patent applications (“parents”) from which our sample patents originate. Continuation, Continuation-in-part, and Divisional are categories of patents (“child” applications) in our sample in relation to their parents. Sample sizes: First sample = 2,276,797, Second sample = 1,004,975, Third sample = 409,577, Fourth sample = 144,282

Table C4. Correlation Matrix for Independent Variables

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. *Figures*	1.00							
2. *Claims*	0.09	1.00						
3. *Scope*	0.06	-0.05	1.00					
4. *IPC*	0.01	0.02	-0.05	1.00				
5. *Cites*	0.18	0.11	0.01	0.04	1.00			
6. *Inventors*	0.10	0.05	0.02	0.06	0.08	1.00		
7. *Family*	0.03	0.03	-0.02	0.24	0.14	0.16	1.00	
8. *Age*	-0.04	0.05	-0.13	0.15	-0.12	-0.05	0.04	1.00

Notes: This table provides the correlation matrix for the first sample. N = 2,276,797

Table C5. Correlation Matrix for Instrumental Variable and its Controls

	1	**2**	**3**	**4**	**5**	**6**	**7**
1. *EDS*	1.00						
2. *ENS_a*	0.00	1.00					
3. *ENS_b*	-0.01	0.13	1.00				
4. *ENS_e*	-0.15	0.13	-0.07	1.00			
5. *ENOS*	-0.03	-0.27	-0.1	-0.26	1.00		
6. *EOS*	0.00	0.13	0.12	0.09	-0.11	1.00	
7. *Exp*	-0.02	0.03	0.02	0.00	-0.1	0.03	1.00

Notes: This table provides the correlation matrix for the third sample. N = 409,577

5 Conclusions

5.1 Overall Context

A patent system is central to a nation's policies that promote technological progress. Patents offer a grand bargain to innovators by providing a temporary monopoly through exclusionary rights in exchange for public disclosure of the patented invention to facilitate the diffusion of codified knowledge among the public. Because of the relevance of patents to innovators, the public, and the economy as a whole, patents are subjects of extensive and longstanding empirical research (see Ribeiro & Shapira, 2020).

Extant literature does not provide a complete understanding of the nature of the relationship between the quality and value aspects of a patent. Further, there is a lack of knowledge of how patent scope, a critical policy variable the optimization of which maximizes social welfare, can be measured based on the meaning of words in the patent claims. Furthermore, there is a lack of empirical evidence on how patent disclosures can benefit the disclosing innovators in the important industrial contexts of markets for technology and finance which offer significant monetization opportunities to the patent holders. Using these complications in literature as anchors, this thesis sets out with the objectives of finding answers to the following research questions: (a1) what are the dimensions of *patent quality*? (a2) (Both a1 and a2 are addressed in the first study), how is *patent quality* related to *patent value*? (b1) how can *patent scope* be measured based on claim interpretation? (b2) what is the extent of the relationship between *patent scope* measured based on claim interpretation and *patent value*? (Both b1 and b2 are addressed in the second study), and (c) what is the extent of the relationship between the *quality* of patent *disclosure* and the *private value* of a patent in the markets for technology and finance? (c1 is addressed in the second study).

This thesis is grounded in the emergent ex-ante theory that proposes a direct and positive relationship between patent quality and patent value. The ex-ante theory adopts a *regulatory* (of the patent office) definition for patent quality, which is *the conformance of a (granted) patent to the statutory standards of patentability*. The regulatory approach has merit because (a) the measurement of patent quality by this method is objective, (b) the approach is consistent with the argument that quality, in general, is measured most precisely when defined as conformance to specifications, and (c) the approach is advantageous compared to alternatives such as the ex-post validity approach that involves measuring patent quality based on the validity of an issued patent and the economist's notion according to which a good quality patent is the one that protects a good idea that is commercialized.

The advantages of the regulatory approach for patent quality stem from the fact that both the alternative approaches discussed above apply to substantially smaller sample sizes as only a small proportion of the universe of patents are commercialized or challenged on validity grounds either at a patent office or in a court. Hence, the findings from patent quality studies based on these alternative approaches are less generalizable. Further, the regulatory lens adopted by the ex-ante theory allows for patent quality to be assessed the moment a patent is granted; this offers an additional benefit to the stakeholders in patents of being able to appraise the patent quality and to an extent, predict patent value *much earlier* in time along a patent's normal life.

The first study links patent quality and value in an elaborated conceptual model. From a microeconomic standpoint, the separation of patent quality and value constructs using a theoretical rationale enables one to understand how patent quality is a determinant of patent value. This understanding is important because it would benefit the major stakeholders in patents such as the innovators, the patent office, and the public who would now have a fair idea of how to assess the quality of patents (the moment it is granted) and how this assessment would impact the patent's value.

The second and third studies closely follow the first study. The second study focuses on a hitherto unknown subdimension of *patent scope* — a subdimension of the *utility* dimension of patent quality explicated in the first study. The third study investigates (for the first time) the relationship between the *quality* of a patent *disclosure* — an aspect of the *sufficiency of disclosure* dimension of patent quality explicated in the first study — and the *private value* of patents in the important contexts of markets for technology and finance.

Though *patent scope* has been studied in a few theoretical papers in the extant literature, the concept has not been operationalized based on claim interpretation; the second study bridges this gap. The third study focuses on the *enablement* aspect of patents, which is the extent to which an applicant for a patent discloses the invention in a manner that is *sufficiently clear* and complete for the invention to be practiced by a skilled artisan. As enablement is the only uniformly applicable disclosure requirement in patents across major geographies (see Ouellette, 2012), the third study considers *disclosure quality* as conceptually equivalent to the quality of enablement. Consistent with Seymore (2010) and Dyer et al. (2020), the third study links the quality of patent disclosures, particularly their *clarity*, to their ease of *readability*; the study adopts the definition of readability from Loughran and McDonald (2014) as the ability of the reader of a patent disclosure to comprehend relevant information in the disclosure.

As discussed in the next three paragraphs, the relationship between the *quality* of patent *disclosure* and the *private value* of patents in the markets for technology and finance (the focus of the third study) emerges from literature based on the principles of information asymmetry and the signaling theory (Long, 2002) of patents. It is noteworthy that the elaborated conceptual model that advances the ex-ante theory (in the first study) explicitly relates these concepts.

In a seminal paper, Levin et al. (1987) suggest a link between the quality of information disclosure and the private value of patents in technology markets by providing an example that potential licensees of a patent may learn about the opportunity to license through the "announcement" effect of patent disclosures. Mazzoleni and Nelson (1998) posit that in one version of the disclosure theory of patents, the information disclosed in a patent would benefit an innovator in certain ways, particularly when the innovator cannot exploit all the uses of the patented invention. In such cases, the extent to which the information disclosed in a patent can attract the attention of an external party, say in the technology markets where patents are licensed or reassigned, would determine the extent to which the innovator can appropriate value from the patent through such external means. Concurring with Mazzoleni et al. (1998), citing the famous Arrow's paradox (1962), Arora and Ceccagnoli (2006) suggest that the quality of information disclosed in a patent is a factor that determines the likelihood of licensing of a patent.

Agrawal, Cockburn, and Zhang (2015) inform that information asymmetry is a factor that imposes transaction costs and causes the failure of markets for ideas. Since information asymmetry and disclosure quality are inversely related (Brown & Hillegeist, 2007), in technology markets, a higher quality of information disclosure in patents would lower the information asymmetry between the trading partners. A reduced information asymmetry would then facilitate transactions in these markets to a greater extent, which would increase the value of the patent to the patentee.

Long (2002) argues that a patent's private value may not *just* be determinable by the rents obtained from the commercial use of the patent in a product market. Innovators can also benefit through other means, for example, by publicizing the information about the invention in patents; this value corresponds to the non-product market value of patents. Long posits that the information disclosed in patents may signal to potential investors about the ingenuity or value of the patenting firm and enable them to make informed investment decisions. In a product-innovation setting, Anton et al. (2003) surmise that enabling patent disclosures can convey positive signals about the disclosing firm and attract investment in capital markets.

5.2 Summary of the Findings

The summary of the three studies with the research questions, research hypotheses, main outcome, and the key takeaway is presented in Table 5. While the first study provides an elaborated model of patent quality and value, the second study provides a valid and reliable measure of patent scope and tests the extent of the relationship of patent scope with patent value based on the proposition of the ex-ante theory. The third study tests the extent of the relationship between the quality of patent disclosure and the private value of patents in the markets for technology and finance based on the proposition of the ex-ante theory.

The key takeaway from the first study is the idea that patent quality and patent value are unique and temporally differentiable concepts if one adopts a regulatory definition for patent quality. The key finding of the second study is the unraveling of a novel subdimension of patent scope based on claim interpretation, and that of the third study is that innovators can benefit by filing patent disclosures of high quality.

Table 5. Summary of Research Studies

Study	First	Second	Third
Research Question(s)	1. How are patent quality and value related in a conceptual framework? 2. What are the dimensions of patent quality and value? 3. How are the different indicators of patent quality and value related to the different and respective dimensions of patent quality and value?	1. How to measure patent scope based on claim interpretation? 2. What is the effect of this patent scope measure on the private value of patents?	For the holder of a patent, what is the effect of the quality of the patent disclosure on the appropriation of value from the patent in the markets for technology or finance?
Hypotheses	None	H: *Ceteris paribus*, the broader the patent scope the higher the private value of the patent	H1: For a patentee, *ceteris paribus*, the higher the quality of disclosure in a patent, the greater the appropriation of value from the patent in the markets for technology. H2: For a patentee, *ceteris paribus*, the higher the quality of disclosure in a patent, the greater the appropriation of value from the patent in the markets for finance.
Outcome	A conceptual model linking patent quality and value	A valid and complementary measure of patent scope. Strong support for hypothesis H.	Strong support (with preliminary causal evidence) for hypotheses H1 and H2.
Takeaway	Patent quality and value are unique, differentiable, and related concepts.	Existence of a novel subdimension of patent scope.	Innovators can benefit by filing patent disclosures of high quality.

5.3 Overall Discussion of the Findings

5.3.1 Theoretical and Empirical Contributions

The first study (SLR) in this thesis adopts the research approach of theory elaboration (Fisher & Aguinis, 2017) that encompasses conceptualizing and executing empirical research using pre-existing conceptual ideas or a preliminary model as a basis for developing new theoretical insights. The consequence of the SLR is an elaborated conceptual model (rooted in the ex-ante theory) that relates the different dimensions of patent quality to those of patent value.

The first study (a) advances a general definition for patent quality based on the standards of patentability adopted by the three major (triadic) patent offices of the world in the U.S., Europe, and Japan, (b) delineates patent quality into four dimensions – *subject matter, utility, non-obviousness or inventive step*, and *sufficiency of disclosure*, and (c) maps the different types of indicators of patent quality and value obtained from the synthesis of the relevant papers in the SLR on to the corresponding patent quality or value dimension. This study also explicates subdimensions of patent quality and value based on a thematic analysis of the various indicators of patent quality and value in the extant literature.

The second study contributes to empirical literature in innovation economics by explicating a valid, stable, and complementary measure of *patent scope*. The study relies on the examination guidelines provided in the U.S. patent statute and associates the occurrence of certain scope-related terms in patent claims that have unambiguous meaning (in the dictionary of the patent office as well as the courts) with a hitherto unexplored subdimension of patent scope. This study contributes to theory by testing the propositions of the ex-ante theory by investigating the strength and directionality of the relationship between patent scope as a subdimension of patent quality (more specifically, the *utility* dimension of patent quality) and patent value; the results are consistent with theoretical predictions. The third study tests the propositions of the ex-ante theory in the particular setting of the markets for technology and finance by investigating the extent of the relationship between the *disclosure quality* of patents and the private value of patents; the results are consistent with theoretical predictions.

5.3.2 Validity and Reliability

In the first study, since patent quality and value are temporally related in a conceptual model, one necessary condition for the *internal* validity of the model is inherently satisfied. In empirical investigations, the other necessary condition of *causality* is extremely difficult to establish because of *endogeneity* in the model. Endogeneity occurs when a dependent variable depends on some unmodeled factors that also drive the independent variable. Several studies on patent quality/value highlight the problem of endogeneity. Reitzig (2004) posits that though patent quality indicators are attractive in patent valuation, their disadvantage lies in their endogeneity because the patent is drafted by the proprietor who can "infer on" the value of the patent. Bessen (2008) argues that innovators can exert varying degrees of effort in the examination and enforcement of their patents. For instance, for a patent application with high potential value, innovators can invest more effort in obtaining more claims or broadening the scope of the claims which would make the patent more resistant to invalidation challenges. They can also include more citations to immunize the patent against possible prior art during litigation. Innovators can also obtain more patents on related technologies to reduce the future threat from competitors. Galasso and Schankerman (2014) inform that technologies with greater commercial potential are both more likely to be protected by patents (with strong rights) and these patents are more likely to be attractive targets for follow-on innovation.

Construct validity generally refers to the vertical correspondence between an unobservable construct and its purported measure (Peter, 1981). *Nomological validity* is the extent to which the relationship between constructs is supported by hypotheses drawn from the underlying theory (O'Leary-Kelly & J. Vokurka, 1998; Peter, 1981). The SLR informs on a myriad variety of measures and indicators for patent quality or value to choose from in future empirical inquiries related to my work. For example, if one has to study the dimensions of regulatory patent quality, the outcome of a factor analysis would contribute to the construct validity of my conceptual model (see Peter, 1981). One can also test the conceptual model based on several hypotheses, the outcome of which would help to establish my model's nomological validity; ultimately, a study's research question(s) or design, the researcher's accessibility to data, and the method of analysis would determine the outcome of the study. Future methodological papers might introduce more precise measures of patent quality or value to the current body of knowledge. Essentially, empirical studies that test the construct and nomological validities of the conceptual model in the future might refine, validate, reorganize, or advance the core ideas (concepts, dimensions, indicators, and measures) that underpin the conceptual model.

For a theory, Calder, Phillips et al. (1982) inform, *external validity* examines whether or not an observed causal relationship should be generalized to and across different measures, samples, contexts, and times. Since external validity is contingent on causality, the problems with the latter also affect the former. Nevertheless, for an empirical researcher, the "applicability" of the conceptual model across different settings can be assessed to an extent by a *meta-analysis*, which

Glass (1976) defines as the statistical analysis of a large collection of analysis results from individual studies to integrate the findings.

Although artificial intelligence (AI) and machine learning (ML) techniques have been used in the past to study patent quality or value, these studies are not a part of this review as the models in these papers do not have the explainable power (for e.g., see Goebel et al., 2018) of traditional econometric or regression models. Nevertheless, explainable AI and ML models in the future can identify latent dimensions of patent quality. Accordingly, the conceptual model remains amenable to future refinements and elaborations.

The dimensions of patent quality in the conceptual model may change over time due to macroeconomic factors. Firstly, national, regional, or international policies or agreements in the future might change the patentability requirements, which might necessitate re-conceptualization(s) of regulatory patent quality or its dimensions which I advance in this review. To provide a context, Mahne (2012) informs that European countries have been striving to create a Unitary Patent which would be valid in all these countries upon issuance and a Unified Patent Court which would have nearly EU-wide jurisdiction over European and Unitary Patents. As per the current EPO notification (see EPO, 2022), Unitary Patents will operate on the rules of the EPC and will have the same standards of examination as European patents. The proposed Unified Patent Court is likely to have a significant impact on the opposition and litigation proceedings for Unitary Patents. Though the broad conceptualizations of patent quality and its dimensions in the SLR seem to be consistent with what would become the standards of patentability for a Unitary Patent, future legislation like this might affect the specifications of patent quality.

In the second study, the measure of patent scope is valid on three counts: (a) it is constructed from certain specific, traditionally used scope-related terms by practitioners in the patent claims that are identified based on their consistent construal by the patent office and the courts in the U.S., (b) on a random sample of 100 patents from my large data, a manual check reveals that the scope measure that is obtained from the text mining algorithm matches with the actual value in 99 patents (this means, the scope measure is reliable to the extent of 99 percent), and (c) consistent with theoretical predictions, the scope measure is positively and significantly (p-value < .10) associated with multiple indicators of patent value. The reliability of the scope measure is also indicated by the nonfluctuating sign of the coefficients for scope in my regression models.

The second study does *not* make *causal* claims as both patent scope and patent value are likely to be driven by the quality of the underlying invention (see Dyer et al., 2020; Kuhn & Thompson, 2019). An instrumental variable may seem an appealing solution, as described by Kuhn and Thompson (2019), to mitigate this endogeneity concern. Kuhn and Thompson successfully use the examiner scope "toughness" as an instrument that's obtained based on the examiner's tendency to reduce the scope of a granted patent compared to its pre-grant publication. Regarding *patent scope*, the study informs that patent examiners do not typically reduce the number of open-ended scope terms in the independent claims of a pre-grant publication during the patent examination; also, patent applicants tend to successfully introduce such terms during the examination. These findings strongly suggest that an instrumental variable akin to that used by Kuhn and Thompson will be unsuitable for *patent scope.*

To facilitate *causal* inference (as endogeneity is a concern in all patent value studies), the third study involves testing the validity of the instrumental variable as an exogenous regressor. The key outcome of this test is that this variable's association with patent value is only through the patent's disclosure quality (the research variable), which strengthens the interpretation of a causal effect of disclosure quality on patent value. This study also uses two different measures of the readability of patents to construct the research variable; the finding is that the results are robust to the choice of the measure. Further, consistent with theoretical predictions, the measure of disclosure quality of patents is positively and significantly (p-value < .10) associated with the private value of patents in the markets for technology and finance.

5.3.3 Limitations and Future Research Directions

The first study advances the ex-ante theory based on a systematic review and synthesis of extant literature. One might adopt an interpretive research philosophy and investigate the concepts and dimensions underlying the ex-ante theory in a social setting. This qualitative research approach could reinforce the findings or further elaborate the conceptual model. Further, the outcome of a factor analysis would contribute to the construct validity of the conceptual model. One can also test the conceptual model based on several hypotheses, the outcome of which would help to establish the model's nomological validity. The "applicability" of the conceptual model across different settings can be assessed by a meta-analysis of the findings from patent quality-value studies.

In the second study, there is no differentiation between the scope-related terms in the patent claims based on the terms' location in the claims. Plausibly, a better scope measure based on claim interpretation would place different weights on the location of the scope terms in the claims; this exercise is computationally intensive and challenging, but it is worth exploring in the future. Another intriguing research angle would involve understanding how the major non-U.S. patent offices of the world such as in Europe and Japan deal with scope-related terms in the claims; this inquiry might enhance the generalizability of the findings from the first study.

The third study uses the Fog index to measure the quality of enabling disclosures. Though the measure is used frequently in assessing the readability of business and finance documents, patents offer a different challenge in being (by design) technically sophisticated. A promising research avenue would involve leveraging natural language processing techniques to develop a more precise measure for the quality of patent disclosures. One can also extend the generalizability of the results by investigating the relationship for patents in non-U.S. geographies (having non-English language) such as Europe, Japan, Korea, and China.

5.4 Managerial and Policy Implications

Regarding the managerial implications, the first study informs that patent quality is a determinant of patent value. This finding should self-incentivize practitioners to invest time and resources while drafting their patent applications to enhance the quality thereof. Innovators can improve the quality of patent applications by ensuring that these, at least satisfy, or better, exceed the standards of patentability laid down by the patent office. Patent drafting and filing are cost and resource-intensive operations in organizations or institutions (either in-house or when outsourced to law firms) looking to protect their intangible assets. The patenting entities should exercise proper diligence to file patent applications of high quality so that they stand a fair chance at increasing the returns from the patented inventions in the lifetime of the patent (assuming that the patents would be granted). Eventually, this strategy would maximize the value of the patents and patent portfolios to the incumbents in the long run.

In the second study, a trend analysis of the scope measure indicates that innovators use the scope-related terms in patent claims to broaden the patent scope in two stages: *strategically* at the patent application stage and *tactically* during the patent examination whilst the patent examiners typically curtail the overall scope of the patent. *Ceteris paribus*, a unit *increase* in patent scope *increases* the private value of a patent between 1.8 and 8.5 percent depending on how the latter is measured. This finding should enlighten managers on the strategic and tactical usage of the scope-related terms in the patent claims to maximize the overall scope of a patent at issuance.

In the third study, the findings suggest that for patents owned by publicly listed firms, *ceteris paribus*, an *increase* in the readability of patent disclosures by 10 percent corresponds to an *increase* in the market value of a patent at grant by 18 percent, and for patents assigned to firms, a similar increase in readability corresponds to an *increase* in the likelihood of reassignment of the patents in the markets for technologies by 7.4 percent. The recommendation to practice is that as the Fog index (a measure of disclosure quality) is based on two factors, average sentence length and proportion of polysyllabic words, patenting innovators should keep sentences short and reduce the proportion of polysyllabic words per sentence. As innovators would have dedicated intellectual property personnel, checking and reducing the Fog index of disclosures before patent filing should not be a practical issue. A Fog index of 16 means the patent disclosure is easily readable by a person having four years of college education (12 + 4 education system). For patents in the research sample, on average, the Fog index value is around 20. The higher the fog index, the lower the readability of patents. Certainly, there is a lot of scope for improving the disclosure quality of patents by innovators.

The first study has implications for patent policy. A theoretically grounded understanding of how the quality of a patent is linked to its value would strengthen the incentives of innovators to file high-quality patent applications and weaken their incentives to file low-quality patent applications (Perel, 2014). Both these factors would enhance the value of patents for an applicant and minimize the costs associated with the rejection of poor-quality applications by the patent office. A reduction in the incidence of poor-quality patents in a patent system would improve the efficiency and reputation of the patent office as patent examiners would be spending less time on substandard patent applications and more time on high-quality (and presumably, more societally beneficial) patent applications. This implication is important because the patent office is often criticized to issue too many patents of poor quality. Further, high-quality patents, once issued, would be less subject to costly and cumbersome litigation (or other legal) proceedings related to patent rights, which would benefit all the parties to such transactions (see Wagner, 2009).

The second study also contributes to the patent policy debate in the U.S. on the quality of issued patents (see Marco et al., 2019). The trend analysis of the scope measure during the grant year range of 2005-2014 suggests that (a) for granted patents, the measure is *increasing*, and (b) the measure for a granted patent *exceeds* that for its pre-grant publication in each grant year. This finding contrasts with that of Marco, Sarnoff et al. (2019) for the other claim-based scope measures such as the number of independent claims or the average number of words per independent claim; the authors attribute the observation to the "stringency" of patent examination following the various patent quality improvement initiatives at the USPTO since 2004. The contrasting finding in this study stands to invigorate the patent quality debate. Since the USPTO explicitly lays down rules on how to interpret the scope-related terms in the claims, the presence of these terms in patents plausibly justifies the patentability standards. The findings in the second study are suggestive of systemic issues in legally authorizing patents with an overly broad scope.

As a policy implication, the results from the third study suggest that enablement as a patent policy variable is beneficial to patent applicants in certain ways; an appreciation of this benefit should incentivize patent applicants to file patent disclosures of high quality, which would help in removing poor quality patents from the system at source and hence improve the efficiency and reputation of the patent office.

5.5 Concluding Thoughts

Patents as intangible assets offer competitive business advantages to innovators. Patent quality and value are topics of burgeoning empirical research. In this thesis, the first study separates the concepts of patent quality and patent value along the temporal dimension and links the dimensions thereof in an elaborated theoretical model, which advances the emergent ex-ante theory. The second and third studies test some aspects of the relationship between patent quality and value in particularly important settings; the empirical results are consistent with the theoretical propositions.

This thesis lays a solid foundation in the field of patent and innovation economics. The findings act as a catalyst for future research on patent quality or value which are of high relevance to innovators, policymakers, and the public alike. I conclude with the final caveat that though I have taken enough steps to enhance the quality of the studies, I take full responsibility for any errors that may be present.

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