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# Assessing the Quality of Financial Technology Patents Through the Development of a Patent Quality Index for Comparing Jurisdictions, Technical Domains, and Leading Organizations

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***Abstract*—This article examines the issue of patent quality in the Financial Technology (FinTech) field and proposes a way of assessing patent quality through the development of a patent quality index based on key indicators proposed in the literature. The index uses a sample of 16 387 patents in the FinTech field registered over 20 years to assess the average quality of patents. To illustrate the utility of the index, the 1) top geographic jurisdictions, 2) top technical domains, and 3) leading organizations were analyzed to map out patterns of intellectual property registration and protection. This article provides significant insights on leading patent jurisdictions, illustrating the growing impact on FinTech of jurisdictions, such as the Republic of Korea, and the focus of patents within the USA in particular domains, such as payment protocols, e-commerce, and identification mechanisms. This article contributes to both theory and practice through the development and validation of a novel patent quality index, which has significant utility to multiple stakeholders and advances knowledge on assessing patent quality. Furthermore, by surfacing a positive association between the quality of an organization's FinTech patents and earnings, the article illustrates the value to organizations in developing high-quality patents in this field.**

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***Index Terms*—Financial technology (FinTech), FinTech index, patent quality, patent strategy, technology roadmap.**

## I. Introduction

THE rapid development of Financial Technology (FinTech) is receiving growing attention across several academic fields, public policy areas, and commercial sectors. FinTech is described as the application of digital technologies, such as algorithms, artificial intelligence, data analytics, and other innovative computer software to the provision of automated and enhanced financial services [1]. Observers from both academia and practice [2], [3] point to technology-enabled innovations in financial services as enablers for new business models, applications, processes, and products, which could revolutionize the provision of financial services [4].

Globally, FinTech has seen massive investment throughout 2021, estimated at $131.4 billion and up 144% from 2020, which could further increase by the end of 2022. The Asia-Pacific and Americas regions account for the most significant share of the global FinTech market, with around 40%, followed by Europe, the Middle East, and Africa with approximately 20% of the total market share [2]. In terms of functionalities, digital payments represent the largest market for FinTech, accounting for more than 80% of global FinTech revenues [2].

The emergence of FinTech has increased the already growing importance of intellectual property (IP) for financial services providers in both offensive and defensive terms [3], [5], [6], [7]. This is particularly the case in areas, such as robotic advice tools, payment processing technologies, and high-frequency trading tools [3], [5], [6], [7], [8], [9]. The rapid pace of change in financial services provision relating to FinTech means that financial services companies are under pressure to 1) make investments in new technology-enabled opportunities, 2) protect their existing technology investments from litigation, and 3) protect their business models from disruption [6], [10]. As a result, the importance of patents for organizations focused on FinTech investments looking to protect and manage their broader IP assets has become increasingly important [5], [6], [7], [10], [11].

FinTech has some crucial differences from the traditional finance sector in terms of IP. FinTech innovations and their impact tend to cut across a number of industry sectors (e.g., Amazon Lending nonbank lending from Amazon, an e-commerce operator, and mobile wallets, such as ApplePay from Apple, which is a technology company) [6], [12]. Besides such specific innovations, many emerging technologies which may not be exclusive to financial applications, also have significant implications for financial services (e.g., cloud computing and distributed ledger technology) [3], [6].

There are also some more general shifts taking place in the finance sector in relation to patents and litigation. High-technology products that act as drivers of financial innovation are bringing new players into the financial sector [6], and patent lawsuits involving financial products are shifting from third-party suits to suits involving competitors (e.g., bank-on-bank litigation) [3], [6].

With established financial services providers and startups both competing and collaborating to develop and deploy FinTech products and services, there are additional reasons for both types of players to "clearly define and protect their IP, especially when working with multiple third parties, so as to control the use of their IP rights, including permitted use under licensing and collaborative arrangements" as described by Medeiros and Chau [7, p. 307].

While the increased IP activities of financial organizations have received some research attention [6], [9], [13], as have issues relating to the content and categorization of FinTech patents [3], [5], less attention has been given to the quality of patents in the finance sector in general, and specifically the FinTech industry. There are significant reasons, however, why patent quality could be an important aspect of IP strategies in the area of FinTech. As Katopis [5] discusses in relation to the USA, record numbers of patents are being awarded at an accelerating pace in the FinTech sector. According to Katopis [5], due to the early stage of the technologies involved and of the FinTech sector itself, as well as the sometimes esoteric technical aspects of FinTech, including blockchain technologies, FinTech patents may be more likely to be associated with spurious or indefensible claims and capital raising, rather than legitimate technical or business purposes.

Further, due to the wide use of open-source licensed technologies in FinTech (especially in blockchain applications) [14], patents may be of questionable relevance and utility. As a result, the FinTech industry may be in danger of finding itself "plagued by a wide variety of poor-quality patents and specious patent litigation," particularly in the USA where the "USPTO's mechanisms for invalidating poor-quality patent claims have been strengthened" both through legislation and recent court rulings [5, p. 25–27].

Having a way to assess the quality of FinTech patents in a timely way, therefore, could provide a useful heuristic in terms of estimating their robustness and rigor and informing further due diligence activities for entities in the sector considering defensive or offensive investments in FinTech IP. This may relate to 1) the acquisition of patents through corporate mergers and acquisitions or through licensing and the resulting valuation negotiations, 2) decisions on whether to fight infringement suits in court or pursue claims against potential infringers, or 3) knowing which factors to pay particular attention to when drawing-up and filing for a FinTech patent in order to maximize its quality and, by extension, its defensibility for a given outlay.

To address the issue of FinTech patent quality and how to measure such quality in order to understand better the value and potential of patents for patent holders [5], this article develops a customized reflective patent quality measurement model to assess unobserved patent quality in the FinTech industry, referred to as the FinTech patent quality index (FPQI).

The article seeks to provide, through the proposed index, a timely way to recognize high-quality patents in the FinTech sector. This enables academic researchers as well as organizations, decision-makers, and policymakers with an interest in FinTech to identify, track, and evaluate FinTech-related patents in terms of quality, in addition to quantity. The FPQI developed is used to assess the average quality of patents by analyzing a sample of 16 387 patents relating to the FinTech field over 20 years.

Furthermore, using the FPQI, the article seeks to address the following research questions relating to patent quality: 1) what is the quality and distribution of patents by organizations involved in FinTech based on the proposed index? 2) what is the distribution of FinTech patent quality based on different jurisdictions? 3) what is the distribution of patent quality in relation to specific technical fields (IPCs)? and 4) is there a relation between the average FinTech patent quality of firms and their earnings?

The remainder of this article is organized as follows. Section II provides an extensive analysis of the literature pertaining to FinTech and patent quality. Section III outlines the research method, including the sample, data, and measures of variables. Section IV presents the developed reflective measurement model and presentation of the new index, followed by details on estimating loadings and weights. Section V presents the application of the FPQI for comparing jurisdictions, technical domains, and leading organizations. Section VI presents the results of our analysis regarding the aforementioned applications. Section VII discusses the critical contributions of the research, outlining how the proposed index can be used to judge the quality and value of IP assets in the field. Section VIII presents key conclusions and opportunities for future article.

## II. Theoretical Framework

Technological advances and innovation change can pave the way for the dominance of new technologies in markets and can play a fundamental role in the knowledge era for the competitiveness of organizations and the economic growth of countries [15]. They also pave the way for dominance over established technologies in existing markets [16] as well as enhancing discovery processes in the R&D strategy of an organization [17].

FinTech is defined by the Financial Stability Board [4] as "Technology-enabled innovation in financial services that could result in new business models, applications, processes or products with an associated material effect on the provision of financial services," with the term FinTech having developed from media usage as an abbreviation for Financial Technology [18]. Financial services as a sector have been at the forefront of technological innovation, since the 1970's [19], [20], [21]. In recent years, the sector has undergone even more radical transformation and change, driven by emerging so-called "unicorn" disruptor organizations and the digital transformation of large financial services incumbents, with large financial institutions increasing their investment in technological innovation over the past few years [9].

The importance for financial services organizations of focusing on FinTech innovation is revealed in existing research with a significant positive association between profitability and FinTech innovation [10], [22], [23]. Companies are applying FinTech to implement new business models and alter the way financial services are offered [24], [25]. This represents process change and service innovation in the business activities of the financial services industry [26], [27], enabled by emerging digital technologies and process innovation [3]. The recent global financial crisis led to a significant increase in innovation in FinTech, enabled by government policy and regulator attentiveness as much as by operational and business strategy reasons [28], [29].

Furthermore, Zhao et al. [10] indicated that FinTech innovation results in better management efficiency for organizations with applications of big data analytics, blockchain, and financial service automation, enabling organizations to simplify and improve their operations. Chen and Chang [13] highlighted that FinTech patents have a significant impact on return on assets for the financial industry and hence, the industry can expend more effort applying for FinTech patents to increase performance. Indeed, Zhao et al. [10] found that the number of bank-owned patents have a beneficial effect on management efficiency and the quality of bank-owned patents potentially increases bank profitability.

Within the financial services industry, research relating to patents has focused so far on the patenting activities of investment banks and revealed a correlation with their size, with smaller organizations failing to obtain patent rights [30]. With FinTech being a fast-moving and increasingly competitive technological field that depends increasingly on the effective management of IP [3], [25], [31], innovative performance, and maximizing return on IP investment will be key for all organizations involved in the provision of financial services.

### A. *Patent Quality*

Many organizations are currently attempting to develop and use multiple tools for analyzing the value of patents [32], [33]. In this context, a good knowledge of patent quality and how to assess it, can support effective decision-making for the organization around its IP [34] as well as encourage R&D investments and commercialization of inventions [35]. At an organization level, how companies manage their R&D collaborations at the knowledge domain level is critical [36]. Indeed, the inclusion of input (e.g., R&D investment) and outcome (e.g., firm profitability and revenues from new products) metrics can be used to evaluate the return on the innovation investment [10], [37].

Within such a context, patent quality is increasingly seen by both academics and practitioners as a key parameter in helping organizations' operations improve their performance relative to competitors [38], [39]. The importance of patents as an indicator of firm innovation is reflected by the fact that Ding et al. [40] employed granted patents as the main measure of firm innovation. However, due to added litigation, licensing costs, and reduced sequential innovation in various industries, there are claims of a decrease in patent quality, leading to diminished innovation, mainly concerning software patents [41].

How to measure patent quality, more generally, is a contentious question in the field of IP, with a multiplicity of approaches used to arrive at a level of patent quality for economic analysis purposes [42]. Even though the research into the evaluation and classification of patent quality is quite fragmented, researchers continue to seek to measure the standard of patent quality through various evaluation criteria.

Many studies that account for variability in the quality of patented innovation use a single indicator, for example, forward citations [34]. The drawback of employing any single indicator over time is that the "production" of the indicator may change over that time [43], but also that the indicator may ignore the relevance and importance of other measures which could be important for specific technologies.

As various combinations of search methods and quality levels of patents are used to study the quality of patents, the approaches and findings reported in the literature from different researchers can be ambiguous or even contradictory [44]. To generate value-weighted patent counts would be a hypothetically appealing solution to this variation, with patent weighting based on the value and importance of these patents. Such a construction would benefit numerous relevant research areas, including, but not limited to, financial technologies [45].

The term "patent quality" has been utilized with various definitions in the economic literature and its meaning varies widely across organizations, patents, and industries over time [46]. The indicators used for the definitions of patent quality focus on the legal validity of a patent's economic value. A common practice in the literature is to qualify a patent system as "strong" when more domains are patentable; when the term of protection is lengthened; when the geographical scope is enlarged; or when patent holders have more power in lawsuits [47]. Furthermore, Guellec and van Pottelsberghe de la Potterie [46] distinguished two factors that explain patent quality: technological value and legal rights. A patent's technical value is determined by its lifetime, breadth, and nonobviousness [48].

Patent quality is undoubtedly a contested and sometimes elusive concept. As a result, many empirical approaches can be found throughout the literature to measure the quality of a patent [42]. Table I presents a description of patent quality variables from the existing literature.

The array of factors that reflect the overall quality of a patent are illustrated in Table I. The methods used vary greatly. For example, some authors rely solely on each patent's monetary value [52], [61] or the present value assessed by experts on a value scale [62]. Others use forward-looking patent citations [63], a composite indicator [43], the likelihood of the patent being granted [64], renewal data and patent opposition [65], or demands for fast-tracked examination by the applicant [66]. Cammarano [67] evaluated the quality of patents through the analysis of forward citations received. A key criticism regarding patent citation indicators is the possibility of examiners requesting citations to be added, rather than applicants being

TABLE I
DESCRIPTION OF ESTABLISHED PATENT QUALITY INDICATORS

| **Variable** | **Description** |
|---|---|
| Claims | Counts the number of claims the patent makes [49]. |
| Non-patent literature | Count of the number of scientific references cited in the prior art of the patent [50], [51]. |
| Backward citation | Count of the number of patents cited that include citations to patents held by its main source [51]. |
| Forward citation | Count of the number of times a patent is cited in subsequent patents [52]. |
| Country | Dummy variables indicate a particular country of the companies in the sample [50]. |
| Year dummies | Dummy variables indicate a particular year in the samples' observed period [50]. |
| Patent cooperation treaty (PCT) | Indicator of whether a patent application was filed as a PCT application [53]. |
| Family size | The number of international patent applications that are connected through their subject matter and that follow claims of priority [53]. |
| International patent classification (IPC) | The number of different IPC classifications assigned to the patent application [53]. |
| Cooperative patent classification (CPC) combination | CPC combination sets are groups of symbols connecting multiple features of an invention to classify different aspects of the main inventive feature that was jointly developed by the USPTO and EPO and is similar to the IPC classification [54]. |
| Examiners | Substantive examination on request within 3 years from the filing date [55]. |
| Grant time | The number of days between filing a patent application and receiving the patent grant. Fewer days means that the patent was granted more quickly [56]. |
| Grant speed | Total years available to effectively use a patent after it is granted and other competitor patents in place [48]. |
| Generality | The percentage of citations received by patent $i$ that belong to patent class $j$ (which is measured by the OST 30 classes) [57]. |
| Assignee count | Count of the number of assignees in a patent document [55]. |
| Inventor count | Count of the number of inventors in a patent document [55]. |
| Legal event | The frequency of legal events related to a patent, including maintenance fee payment, lawsuits involved, and patent ownership transference [56]. |
| Patent count | The number of applicants having applied for the patent [58]. |
| Maintenance time | The higher the quality of a patent, the longer its maintenance time [45]. |
| Independent claim length | The number of words used in the shortest independent claim [54]. |
| Probability of early lapse | This relates to the probability that the granted patent will lapse before the available term [59]. |
| Probability of grant | The probability of a grant is defined in relation to patents that are granted by patent offices in exchange for a full disclosure of the invention [60]. |

willing to include them, reducing their importance as a measure of knowledge flows [68]. Such diversity of measures makes the assessment and comparison of patent quality difficult, as there is no consensus on evaluating the quality of a patent.

Therefore, to construct a comprehensive FPQI, we conducted an extensive literature analysis, searching published articles in Scopus and Web of Science databases for the period 2000–2020. We searched the patent literature for patent-related keywords. For example, we searched for "patent quality," "patent value," and "patent index," all of which could have the same meaning. Then we selected articles that included any terms related to patent indicators or analysis of patent quality. Of 44 studies focused on patent quality, 22 were chosen to be scrutinized based on their relevance to patent quality indicators (Table II). In total, 17 unique indicators were identified in the literature, with each indicator reported at least twice in publications focused on patent quality. This approach to selecting the most frequently referenced indicators from the literature is in line with established practices [69], [70].

Utilizing the practice of indicator selection based upon number of occurrences in the literature (Table II), this article proceeds with constructing an index based on the FPQI indicators using the top six indicators, namely: forward citation, backward citation, nonpatent citation (NPL), claims count, family size, and four-digit IPC classes.

## III. Research Method

The advantage of the indexation approach and the benefits of aggregation allows us to develop comprehensive conclusions with respect to patents' quality at a 1) microlevel (organization), by assessing the firm's individual patent quality, 2) macrolevel (country), by assessing the average patent quality of each jurisdiction of interest, and 3) technical-level (IPC), by assessing the quality of a patent in a specific technical field. Indeed, indices have already been developed and used in the context of business literature to provide information with respect to

TABLE II
KEY PATENT INDICATORS ESTABLISHED IN THE LITERATURE

| No | Study | Indicators (quality attributes) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Patent family count | Claim count | Number of IPC (scope) | Forward citations | Nonpatent literature references (NPL) | Maintenance time | Generality | Regions/ country | Grant/priority year | Independent claim length | Examiners /legal | Patent count in the field | PCT | Backward citations | Inventor count | Assignee count | Grant speed/count |
| 1 | Harhoff et al. [61] | ✓ | | ✓ | ✓ | ✓ | | | | | | | | | ✓ | | | |
| 2 | Lanjouw and Schankerman [43] | ✓ | ✓ | | ✓ | | | | | | | | | | ✓ | | | |
| 3 | Sapsalis et al. [71] | ✓ | | | | ✓ | | | | | | | | | ✓ | ✓ | ✓ | |
| 4 | Bessen [72] | | ✓ | | ✓ | | | ✓ | | | | | ✓ | | ✓ | | | |
| 5 | Harhoff and Wagner [53] | ✓ | ✓ | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | ✓ | | | |
| 6 | Van Zeebroeck & Van Pottelsberghe de la Potterie [73] | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| 7 | Petruzzelli et al. [50] | | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | |
| 8 | Fischer & Henkel [49] | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | ✓ | | ✓ | | | |
| 9 | Sterzi [57] | | ✓ | | ✓ | ✓ | | ✓ | | ✓ | | | | | | ✓ | | |
| 10 | Chen [56] | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | |
| 11 | Agostini et al. [74] | | | | ✓ | | | | ✓ | ✓ | | | ✓ | | | ✓ | ✓ | ✓ |
| 12 | Wu et al. [55] | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | |
| 13 | Chang and Fan [75] | | ✓ | | ✓ | ✓ | | | | | | | ✓ | ✓ | | | | |
| 14 | Chang et al. [45] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | | |
| 15 | De Rassenfosse and Jaffe [76] | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | |
| 16 | Marco et al. [54] | | ✓ | | | | | | | ✓ | ✓ | ✓ | | | | | | |
| 17 | Cirillo [77] | | | | | | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | |
| 18 | Mukundan et al. [48] | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | | | | ✓ | | | ✓ |
| 19 | Le Gallo and Plunket [58] | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | ✓ | | ✓ | ✓ | | |
| 20 | Thompson and Woerter [78] | ✓ | ✓ | | ✓ | ✓ | | ✓ | | | | | | | | | | |
| 21 | Liu et al. [34] | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | ✓ | ✓ | ✓ | ✓ | |
| 22 | Li et al. [79] | ✓ | ✓ | ✓ | ✓ | | | | | | | | | ✓ | ✓ | | | |
| **Total Count** | | 14 | 17 | 12 | 18 | 14 | 4 | 4 | 8 | 10 | 2 | 3 | 6 | 5 | 14 | 10 | 8 | 2 |

different markets and products. For example, indexation approaches have been used by several studies to estimate cultural distances based on deviations from Hofstede's [80] national scores [81]. Others have been used to capture differences across jurisdictions on trade policy, taxation policy, government consumption of economic output, monetary and banking policy, capital flows and foreign investment, wage and price controls, property rights, regulatory climate, and black-market activity by measuring deviations of the Economic Freedom Index[1] [81], [82], while others use the indexation approach to estimate the potential of emerging markets through a combination of economic, cultural, and infrastructural aggregates [83], [84].

By using a combination of variables, the development of an index enables the better assessment of patent quality, relative to any single variable used for its construction. Thus, the aggregation process that leads to the creation of indices provides a better understanding of markets, contributes to the design of more suitable market strategies and programmes, helping corporations and organizations to focus on those patents that have the greatest chance of being successful, identifying new marketing opportunities, as well as finding more effective allocation of financial and other resources.

### A. Sample and Data

To analyze FinTech patenting trends, data were collected from the Derwent Innovations Index (DII), which is one of the most comprehensive databases of international patent information, including 70 million described patents. We searched for patents between 2000 and 2019 (December 31st). A search strategy based on keywords relevant to FinTech was used since a search based on IPCs would be challenging due to the multidisciplinary nature of the FinTech sector. Different combinations of 35 keywords (see Appendix I for the details of keywords) were used that were deemed to be most likely to relate to FinTech based on a careful review of the previous FinTech scientific literature [3], [25]. Keywords were searched in the patent title and the abstract since they provide the most concise and accurate description of a patented invention. The search process identified a total of 16 387 patents.

In addition, to further test our constructed index, we collected data from the Thomson–Reuters database on Revenue and EBITDA[2] (earnings before interest, taxes, depreciation, and Amortization) for 37 selected companies. Finally, we test our proposed index against some universal metrics in FinTech, by considering the Findexable Global Index score (https://findexable.com).

### B. Measures of Variables

All the data collected from the DII [e.g., backward citation, forward citation, nonpatent citation (NPL), claims count, family, and IPC classification] and the Findexable Global Index are expressed in pure units. Further, data collected from the Thomson–Reuters database, such as Revenue and EBITDA, are measured in millions of U.S. dollars.

[1][Online]. Available: https://www.heritage.org/index/

[2]EBITDA stands for earnings before interest, taxes, depreciation, and amortization, and is a metric used to evaluate a company's operating performance. EBITDA facilitates analysis through enabling comparison of the profitability between companies and industries, as it eliminates the effects of financing, government, or accounting decisions.

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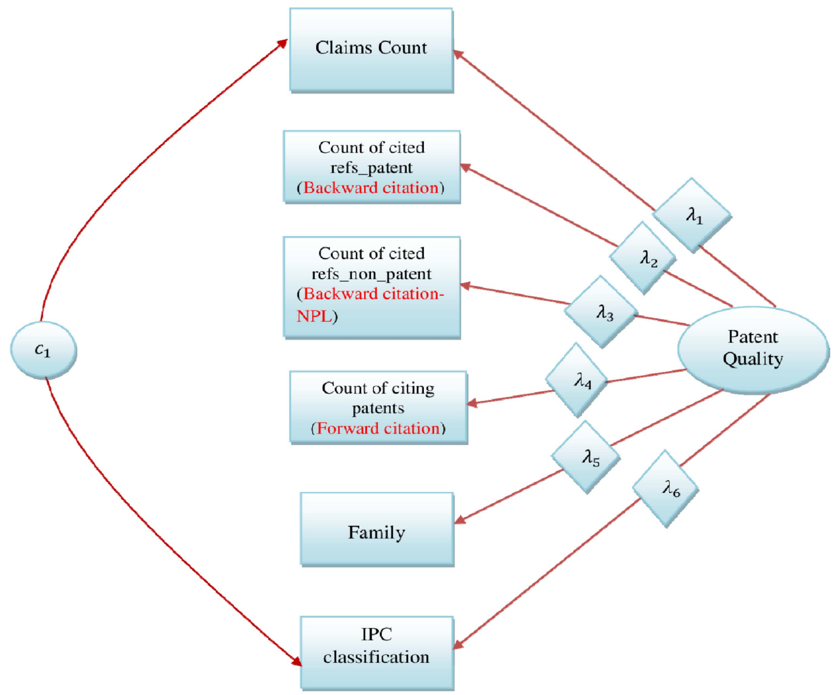


Fig. 1. (Reflective) proposed model.

## IV. Toward Construction of the FinTech Patent Quality Index

This section discusses and introduces the proposed index by focusing on the procedure and the statistical techniques used for its construction. Then, the estimated parameters of the basic model used in constructing the FPQI are presented.

### A. *Index and Data Analysis Procedure*

The construction of an FPQI is based both on the selection of a set of indicators derived from the established literature and the use of statistical methods, such as structural equation modeling (SEM) techniques. Specifically, our proposed index that assesses the unobserved patent quality is developed as a linear combination of the observed indicators multiplied by their weight. Thus, for each patent $j$ its quality is given by formula 1 (F.1)

$$PQ_j = \sum_i w_i y_{ij}$$

where $PQ_j$ stands for patent Quality and denotes the patent quality of patent $j$, which is reflected in the weighted sum of the observed indicators. $w_i$ is the weight of the indicator $y_i$.

The weights of the observed indicators are calculated by applying the following formula 2 (F.2):

$$w_i = \frac{\lambda_i}{\sum_i \lambda_i}$$

where $\lambda_i$ is the factor loading of indicator $y_i$, estimated by the following reflective measurement model analytically presented in Fig. 1.

By construction, weights are percentage units and our proposed index takes positive values. Additionally, our index is said to be in a consistent state since it is a good representation of its corresponding database state. We reach this conclusion after the construction of our index and its application in our dataset, by showing that it is highly associated with each single indicator used for its construction (See Appendix II for further information). We proceed with the construction of our index by considering that the unobserved patent quality is not affected by any observed explicit variable. On the contrary, existing patent quality can influence a set of explicit variables. Thus, the same variables can be used to reflect patent quality [45]. Due to this mechanism, we consider a reflective measurement model to describe the relationship between the patent quality (latent variable) and a set of explicit variables (observed variables).

In SEM, a reflective measurement model is a multivariate statistical analysis technique that is used to analyze and study structural relationships [85], [86], [87]. This technique combines factor analysis and multiple regression analysis to explore the structural relationship between measured (observed) variables and latent (unobserved) constructs. The analytical consideration of the previous theoretical and empirical studies on patent quality shows that our proposed methodology related to the factor analysis represents and underlies the notion of "quality." Fig. 1 illustrates an analytical representation of our structural equations model.

Patent quality is our latent variable, while the variables within the boxes are the observed patent indicators. The one-directional arrows describe the structural relationship between the latent and the observed variables; $\lambda$'s denote the factor loading coefficients. A squared standardized factor loading (i.e., $\lambda_i^2$) indicates the proportion of variance in the explicit variable $y_i$ that is explained

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TABLE III
ESTIMATED LOADINGS FOR EACH INDICATOR

| Indicators ($y_i$) | Estimated loadings ($\lambda_i$) |
|---|---|
| Claims count | 0.08*** (0.009) |
| Backward citation | 0.68*** (0.01) |
| NPL | 0.82*** (0.014) |
| Forward citation | 0.23*** (0.008) |
| Family | 0.13*** (0.009) |
| IPC classification | 0.071*** (0.009) |
| $c_1$ | 0.39*** (0.007) |

*p ≤ 0.1
**p ≤ 0.05
***p ≤ 0.01
Note: NPL stands for non-patent citation; IPC stands for international patent classification.

by the patent quality (i.e., latent variable). It follows that $(1-\lambda_i^2)$ provides the proportion of the explicit variable's variance that is not explained by patent quality [86], [87].

We estimate our proposed SEM (Fig. 1) by considering the standard maximum-likelihood estimation [85]. Moreover, the bidirectional arrow, denoted by $c_1$, indicates a correlation between the "claims count" and "IPC classification" indicators, based on the notion that some of the covariances in these indicators are not explained by the latent variable and instead are due to another common exogenous cause. Specifically, to measure patent scope, two approaches are classically involved in the existing literature: 1) counting the number of technological classifications assigned to the patent (IPCs) [63], and 2) counting the number of claims in the patent. The patent has high practical value when many technical fields are included in a patent. Lerner [63] suggested that the number of IPCs can symbolize the scope of the patented invention and is highly associated with its market value [45].

The number of claims has been exercised substantially as a sign of an invention's breadth and profitability. Claims can codify the description of the invention and establish the scope of protection in case of a grant. Furthermore, a more significant number of claims referred to in a patent represent a breadth of patent protection [43]. Therefore, some of the shared variances between these two indicators (i.e., "claims count" and "IPC classification") are due to the latent factor (i.e., "patent quality"), while some of the shared variances are due to an external cause (i.e., "patent scope").

## B. Estimating Loadings and Weights for the Index

After estimating our reflective measurement model, we obtain the estimators for the factor loadings. Then, we use them to construct a patent quality index based on the weighted sum of the above-observed indicators.

By estimating the reflective measurement model, we obtain the factor loadings $\lambda\prime s$ for the six indicators $y\prime s$ of patent quality in the FinTech field. Table III presents the standardized estimated loadings and their standard errors in parenthesis. Moreover, it provides us with the estimation of the correlation $c_1$ between the variables "claims count" and "IPC classification" and their standard error.

Table III shows that the estimated factor loadings $\lambda' s$ for the backward and forward citations, the family size, and the IPC classification are statistically significant at $a = 1\%$. In contrast, the estimated factor loading of the number of claims is statistically substantial at $\alpha = 5\%$. It is also shown that the factor loading of the indicators "backward citation," "NPL," and "forward citation" are higher than those of "claims count," "family," and "IPC classification." This implies that patent quality is reflected more on the indicators that are related to backward and forward citations and less on those related to the number of claims, family size, and IPC classification. Despite the magnitude of the estimators, they are all statistically significant and reflect a great part of the unobserved patent quality. By following the guidelines that come from the findings of simulation studies conducted by Hu and Bentler [88] and [89] concerning the comprehensive evaluation of cutoff criteria of fit indices, we find that all the goodness-of-fit indices obtained indicate that the model fits well. Specifically, we conclude that the model fits well the data based on the following goodness-of-fit indices. The value of root mean square error is low and equals 0.086, comparative fit index and Tucker–Lewis index are 0.910 and 0.831, respectively, and coefficient of determination, which is like an $R^2$ for the whole model is 75%, which indicates a very good fit.

To construct a patent quality index, we need to convert estimated factor loadings into percentage weights by using F.2. Thus, the percentage weights of each indicator are presented, in Appendix III, which reveals that the indicators related to backward and forward citations have higher weights. Then, by applying F.1 of the patent quality index in our FinTech sample, which consists of 16 387 patents, we obtain the mean patent quality in our sample, equal to 8.5, with its standard deviation being 32.72. The maximum value of the index is 1309.77, while the minimum value is 0.14.

## C. Application of FPQI for Comparing Jurisdictions, Technical Domains, and Leading Organizations

After constructing our proposed index by following the procedure above, we further proceed by testing the constructed index (FPQI) in three different cases, i.e., country-level analysis, technical field (IPC)-level analysis, and organization-level analysis.

*1) Country-Level Application:* First, we proceed with the country-level analysis, by identifying potential differences across jurisdictions for 1) patent quality, as our index captures it, and 2) every single indicator used to construct the index. Based on sample size availability, we consider five jurisdictions, i.e., the USA, China, Europe, Japan, and Korea (total sample size 16 387 patents). We observe that the USA is the leading jurisdiction in terms of registered patents number, as it accounts for a total of 39.5% of the sample. China accounts for the second position with approximately 15.5% of patents, while Korea is at the third rank, which accounts for 12.2% of the total sample. Patents in Europe and Japan represent approximately 7.1% and 7.8%,

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TABLE IV
MEAN SCORES FROM FPQI BY INDICATORS

| Jurisdiction | Patent quality | Claims counts | Backward citation | Backward citation_NPL | Forward citation | Family size | IPC classification |
|---|---|---|---|---|---|---|---|
| **USA** | 16.99 | 21.03 | 30.91 | 6.16 | 15.72 | 21.03 | 3.29 |
| **China** | 2.39 | 18.55 | 1.98 | 0.24 | 1.62 | 9.89 | 2.56 |
| **Europe** | 3.65 | 21.59 | 2.74 | 1.18 | 0.71 | 19.62 | 3.11 |
| **Japan** | 3.89 | 24.04 | 3.59 | 0.11 | 2.53 | 21.14 | 3.00 |
| **Korea** | 2.34 | 19.38 | 2.01 | 0.25 | 0.98 | 9.11 | 3.19 |

Note: NPL stands for non-patent citation; IPC stands for International Patent Classification.

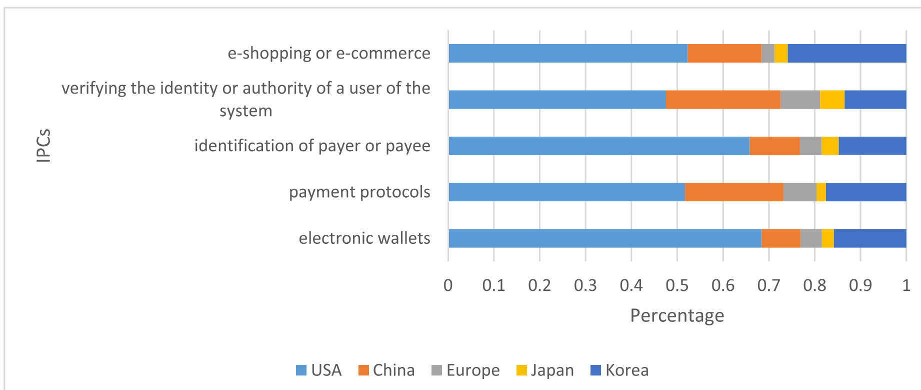


Fig. 2. Sample balance of IPCs across jurisdictions.

respectively. These five jurisdictions count for more than 82% of the total sample size.

Regarding the country-level analysis, we used patent applications in time by considering the application year instead of the granting year. The application year is closer to the point in time when the invention is developed since the granting process typically takes a long time [90]. Instead, to assign a patent application to a country, we used the applicants' location and computed the sum of each country's fractional count of applications [76]. Then, we study whether there are significant differences between the mean scores of the considered jurisdictions for 1) patent quality and 2) every single indicator by considering a one-way between-groups analysis of variance (ANOVA) [91]. These were further explored by conducting *post-hoc* comparisons and bilateral tests where significant differences were identified by the Bonferroni correction [92], [93]. Table IV illustrates the mean scores of each independent variable for each jurisdiction.

According to the results presented in Table IV, we observe that the USA is by far the leading jurisdiction for patent quality as its mean score (16.99) is much greater than the mean scores of patent quality in China (2.39), Europe (3.65), Japan (3.89), and Korea (2.34), respectively. In a similar vein, the mean scores of the USA concerning the variables Backward Citation, Non-Patent Literature (NPL), Forward Citation, and marginally for the variable IPC Classification are higher than those of the rest of the jurisdictions. However, for the variable Claims Counts, the mean score of Japan is the highest, followed by Europe, the USA, Korea, and China, respectively. Concerning the variable Family size, Japan has the highest mean score, closely followed by the USA and Europe, while China and Korea appear to have the lowest mean scores.

*2) Technical Field Application:* Next, we proceed with technical field-level analysis, by considering the top five IPCs based on the sample size availability in FinTech. IPC enables users to find a detailed patent document and its technical fields or an informative technology overview by IPC categories relating to a specific technology. Therefore, we consider G06Q3002, which stands for *e-shopping or e-commerce*, HQ4L0932, which stands for *verifying the identity or authority of a user of the system*, G06Q2040, which stands for *identification of payer or payee*, G06Q2038, which stands for *Payment protocols*, and G06Q2036, *electronic wallets*. Fig. 2 illustrates a crosstab analysis for the jurisdictions across different IPCs.

For all selected IPCs, the USA is the leader pertaining to the number of patents, China and Korea follow, while Europe and Japan have the fewest number of patents for each IPC. For each of these IPCs, we study whether there are significant differences in patent quality between the five chosen jurisdictions, by using ANOVA tests and *post-hoc* tests.

*3) Organization-Level Application:* Finally, we analyzed the identity of the leading patent organizations in the FinTech domain in the world, as suggested by Albino et al. [90]. This analysis identifies organizations involved in developing FinTech solutions. We consider data for to Revenue and EBITDA for all the companies in our sample for which data were available. This was done to study the relationship between their average

TABLE V
MEAN SCORE OF THE SELECTED PAIRS OF JURISDICTIONS

| Pairs | Patent Quality | Claims Counts | Backward Citation | NPL | Forward Citation | Family size | IPC Classification |
|---|---|---|---|---|---|---|---|
| USA–China | USA*** | USA*** | USA*** | USA*** | USA*** | USA*** | USA*** |
| USA–Europe | USA*** | – | USA*** | USA*** | USA*** | – | – |
| USA–Japan | USA*** | Japan*** | USA*** | USA*** | USA*** | – | USA** |
| USA–Korea | USA*** | – | USA*** | USA*** | USA*** | USA*** | – |
| China–Europe | – | Europe** | – | – | – | Europe** | Europe*** |
| China–Japan | – | Japan*** | – | – | – | Japan*** | Japan*** |
| China–Korea | – | – | – | – | – | – | Korea*** |
| Europe–Japan | – | – | – | – | – | – | – |
| Europe–Korea | – | – | – | – | – | Europe** | – |
| Japan–Korea | – | Japan*** | – | – | – | Japan*** | – |

*$p \leq 0.1$ ;
**$p \leq 0.05$
***$p \leq 0.01$
Note: NPL stands for non-patent citation; IPC stands for International Patent Classification.

FinTech patent quality, as calculated using our index, with their revenue and earnings before taxes. To ensure a consistent data collection standard, the chosen organizations should meet the following criteria: 1) the company must be listed on the stock market; and 2) the company must have a minimum of one granted patent in the FinTech field. The details of companies and related information regarding patent count, revenue, and EBIDITA are listed in Appendix IV.

According to the aforementioned criteria, the total number of registered patents for all 37 selected companies is 4367 patents, approximately 26.65% of the total dataset used to construct the patent quality index in the previous sections.

We use the constructed index (FPQI) to calculate the average FinTech patent quality for each selected company. Similarly, based on the data collected from the Thomson–Reuters database for the same period, we calculate each company's average revenue. Then, to study and describe the *association* between the average FinTech patent quality of a company against its average revenue, we consider the following regression model between these two variables. Therefore, for a company $k$

$$\ln\left(\text{Average Fintech Patent Quality}\right)_k = \alpha_k \ \ln(\text{Average Revenue})_k + \ u_k.$$

The association between the average FinTech patent quality of a company and its average revenue are presented in the below section related to organization-level results.

## V. RESULTS

In this section, we present the results of the analyses, discussed in the previous sections. Specifically, we present the results from the country-level analysis, the technical field (IPC)-level analysis, and finally, the organization-level analysis.

### A. *Country-Level Results*

A one-way between-groups ANOVA is conducted to establish the significance of differences across the five jurisdictions for 1) patent quality and 2) every single indicator used in the construction of the index. This is followed by $t$-tests between pairs of jurisdictions, where significant differences are indicated. Table V illustrates the differences in mean scores between pairs of jurisdictions for the aggregated patent quality index and each indicator used to construct the index separately.

For the total sample, we observe that, on average, the patent quality is higher in the USA compared to its rivals, i.e., China, Europe, Japan, and Korea. At the same time, no big differences

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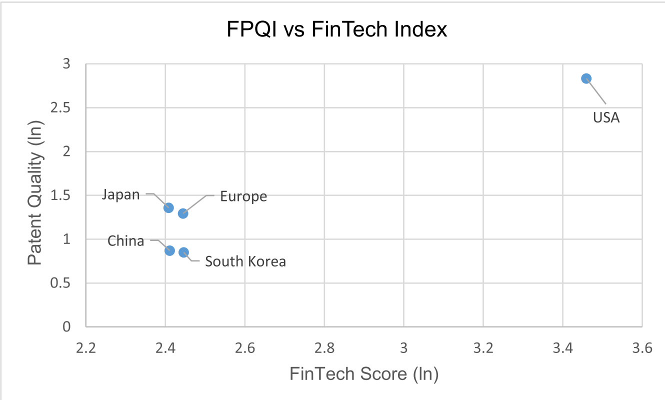


Fig. 3. Comparison of FPQI and the Findexable index score.

are identified between the other pairs of jurisdictions for the mean scores of the patent quality. These results follow those from the indicators that count for backward citations (i.e., backward citation and NPL) and forward citations (i.e., forward citation). For the backward and forward citation indicators, the USA mean score is higher than those of China, Europe, Japan, and Korea, while no differences were identified for the other pairs. Moreover, some variations exist for the remaining indicators. Specifically, the mean scores of "claims count" in both the USA and Europe are higher than that of China, while Japan's mean score is higher than those of the USA, China, and Korea. Similarly, for the "family" variable, the USA, Europe, and Japan's mean scores are higher than China's and Korea's. Finally, for "IPC Classification," the mean scores in all jurisdictions are higher than that of China, while the USA scores higher than Japan.

The Findexable Global Index ranks the FinTech ecosystems of 65 countries worldwide and has been widely used in the academic literature to capture the overall performance of global FinTech jurisdictions [94]. To further strengthen the results of our country-level analysis and to test the robustness of our proposed index against some universal metrics in FinTech, we considered the Findexable Global Index score as a supplementary tool to compare the jurisdictional ranking of the FinTech ecosystems included with our FPQI ranking. Fig. 3 illustrates the association between the mean scores of our patent quality index (vertical axis) and the Findexable Index score (horizontal axis).

The analysis illustrates that the USA is the leading jurisdiction both for the mean patent quality and the FinTech index score, with its FinTech score being higher than China, Europe, Japan, and Korea. As illustrated in Fig. 3, Japan, Europe, China, and South Korea have similar rankings, indicating minor variations in their FinTech scores. These results reveal no significant differences concerning mean scores of patent quality for these four jurisdictions. There is an alignment between the FPQI and the Findexable Index score, illustrating the importance and contribution of patenting to overall FinTech activities in the jurisdictions studied.

### B. *Technical Field-Level Results*

We proceed by carrying out an ANOVA test, with Bonferroni correction for each IPC, and then we run *post-hoc* tests between different jurisdictions. Table VI presents the results of our analysis.

Concerning the G06Q2036, the ANOVA test reveals no significant difference in the mean scores of patent quality between jurisdictions. Moreover, for the other IPCs, namely G06Q2038, G06Q2040, H04L0932, and G06Q3002, we found that the mean patent quality score is higher in the USA compared to the scores in China and Korea, respectively. No other significant differences are identified.

### C. *Organization-Level Results*

Table VII presents the results of the regression analysis model described in the previous section.

Our results show a statistically significant positive correlation (i.e., $a = 1\%$) between a company's average FinTech patent quality and its average earnings. Further, we also study the robustness of the results by considering the average EBITDA as a measure of the profitability of the companies. After conducting another regression analysis between the average patent quality and the average EBITDA, we found a positive correlation between companies' average profitability, as measured by EBITDA, and their average patent quality.

Fig. 4 illustrates the relative trends between companies' average patent quality and their average annual financial measures (i.e., revenue and EBITDA) without direct comparability regarding units and scales. Also, a table that includes detailed information on selected companies can be found in Appendix IV.

## VI. Discussion

This article examines the issue of patent quality in the field of FinTech, patenting activities in key jurisdictions together with the operational performance of organizations involved in patenting FinTech IP. A novel *FPQI* was derived from indicators in the existing literature, which was subsequently tested in relation to 1) geographical jurisdictions of patent priority, 2) IPCs (technology class fields), and 3) organizations' earnings. This article extends the existing knowledge base pertaining to patenting activities, especially in the FinTech domain, and the learnings are of value to multiple stakeholders, including academia, private sector organizations, and policymakers.

Patents in the FinTech sector are being awarded at an accelerating pace; however, due to the early stage of technology progress in some FinTech fields, patents may be linked to indefensible claims and capital raising rather than legitimate technical or business purposes [5]. Furthermore, strong anti-patent sentiment exists in some FinTech areas, for example, blockchain technology, which has led to a form of open-source patenting activity [14]. Given these circumstances, we were motivated to assemble from the existing literature the most relevant indicators to construct a patent index and examine its efficacy in the case of

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TABLE VI
MEAN SCORE OF PATENT QUALITY BASED ON THE SELECTED IPCS

| **Pairs** | Electronic Wallets (G06Q2036) | Payment protocols (G06Q2038) | *Identification of payer or payee* (G06Q2040) | *Verifying the identity or authority of a user of the system* (HQ4L0932) | *E-shopping/ e-commerce* (G06Q3002) |
|---|---|---|---|---|---|
| **USA–China** | – | USA*** | USA** | USA*** | USA** |
| **USA–Europe** | – | – | – | – | – |
| **USA–Japan** | – | – | – | – | – |
| **USA–Korea** | – | USA*** | USA*** | USA** | USA*** |
| **China–Europe** | – | – | – | – | – |
| **China–Japan** | – | – | – | – | – |
| **China–Korea** | – | – | – | – | – |
| **Europe–Japan** | – | – | – | – | – |
| **Europe–Korea** | – | – | – | – | – |
| **Japan–Korea** | – | – | – | – | – |

*p ≤ 0.1
**p ≤ 0.05
***p ≤ 0.01

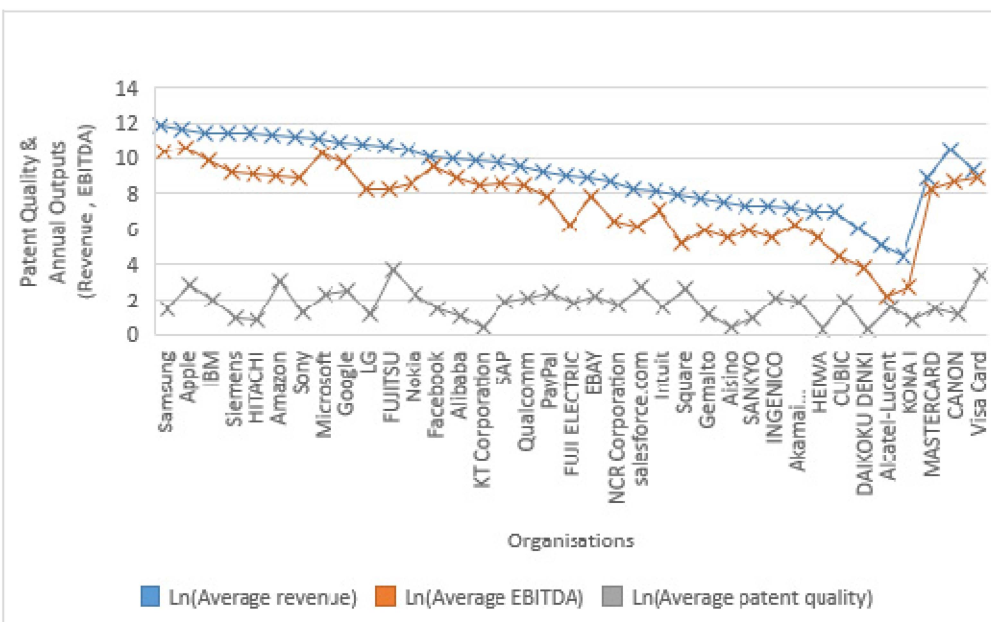


Fig. 4. Visual representation of revenue, EBIDTA, and patent quality of the 37 firms studied.[3]

FinTech. In comparison to previous indices, the FPQI follows an updated approach with a holistic view of all the existing recorded literature to create the proposed index. Indeed, much of what is explained by previous indices depends heavily on the citation indicators; however, we included other indicators (e.g., claims and family size), thereby going beyond backward and forward citations to measure patent quality.

Numerous academics and practitioners endorse the importance of strategies in patent filing in emerging technologies

[3]Note: In the part of the graph where the red line (average patent quality) with two other lines (yellow and green) are the least distant from each other, it can be inferred that the company has a better financial performance in terms of its quality patents portfolio. This is relevant to organisations, such as Kona I, Alcatel, PayPal, and Square Inc.

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TABLE VII
REGRESSION ANALYSIS

| | ln(Average patent quality) |
|---|---|
| **ln(average revenue)** | 0.19***<br>(0.015) |
| | |
| **R-squared** | 0.81 |
| **Adj R-squared** | 0.80 |
| **F-stat (1, 36)** | 152.54*** |
| **Obs** | 37 |

* $p \leq 0.1$
** $p \leq 0.05$
*** $p \leq 0.01$
Note: Standard error is reported in parenthesis.

[14], [70], [95]. Through an extensive literature review of patent quality studies, we collected and analyzed all possible indicators reported in the literature that have been used to assess the quality of patents in several fields, including but not limited to FinTech. This analysis provides some important insights regarding patent quality and enhances knowledge about the structural relationship between all those indicators and the unobserved variable of the *quality of patents*. Furthermore, this article illustrates the value of patenting by showing the positive relationship between patenting and organization earnings, illustrating the performance benefits for organizations in filing patents, in line with the findings of Ding et al. [40].

Exploring patent jurisdictions in more detail, this article reveals a substantial increase in the rate of registered patents and the quality of registered patents in the USA between 2016 and 2020, aligned with previous studies in other established industries [96]. It also reveals a significant increase in claims counts in some geographical jurisdictions, such as South Korea, illustrating South Korea's growth as a jurisdiction with significant FinTech innovation activities. Japan appears to position itself as the strongest country for IP protection, by emphasizing the scope and boundaries of a patent. Indeed, Japan's positioning within FinTech innovation seems to have evolved from leading the USA in 2000 in terms of the number of patents filed (86 patents vs. 71 patents), a position it retained until 2006, to a situation in 2019 where the USA had 954 patents to Japan's 68 patents. This would suggest a reduced focus on FinTech patents in Japan. Further, it is pertinent to mention that in some subclasses of the FinTech field, such as blockchain technology, previous articles [14], [95] found that the USA and China are among the two leading countries for patent activities in the field. However, we did not observe this for China when it comes to the quality of registered patents.

Focusing specifically on the FinTech domains, it is clear from our findings that particular jurisdictions dominate. The USA, for example, has been a pioneer in most of the technological fields related to FinTech, particularly payment protocols, e-commerce, and identification of payee and payer technology. However, in areas such as "electronic wallets," no one country dominates and countries, such as the Republic of Korea, have illustrated significant activity in this area, reflected both in terms of the quality and quantity of patents

Considering all of the above, this article has some important implications for practice. Identifying high-quality patents promptly can boost the probability of success of an organization aiming to compete on the IP front in the FinTech sector. Our FPQI can assist in this regard. It enables organizations to assess the quality of organization patents and helps inform the development and deployment of FinTech technologies through, for example, collaborative partnerships and/or IP licensing agreements. Furthermore, the FPQI can potentially be used to guide assessments of the quality and value of an organization's IP assets and potential, in a merger or acquisition situation, or when deciding whether to invest in defending patents held.

In March 2021, Technisys (a company behind a next-generation core and digital banking platform) announced its acquisition of Kona I,[4] a South Korean company, and pioneer in artificial intelligence chatbots based on its registered patents. This acquisition illustrates the value of this article, which highlighted Kona I (one of the 34 companies analyzed in this article) as a leader in terms of the quality of patents. This example helps to illustrate the potential usefulness of the FPQI as a tool for identifying high-quality patents held by organizations that may be fruitful targets for alliances/takeovers/investments.

Beyond academia and industry, the FPQI can also allow policymakers to better understand their jurisdictions' standing in terms of patenting within FinTech, thereby informing policy for to improving their jurisdictions' attractiveness as a destination for FinTech innovation [97].

## VII. CONCLUSION

As the FinTech sector evolves, the valuation of organizations with FinTech activities and IP strategies will likely become more critical. Organizations and investors will require practical approaches to valuing IP and commercial portfolios. As reported in previous article [10], [98], FinTech innovation results in better management efficiency with applications of big data analytics, blockchain, and financial services automation described as enabling organizations to simplify and improve their processes. Having up-to-date insights on high-quality patents as enabled by the FPQI, therefore, represents a significant informational and strategic resource for organizations and managers. It provides them with insights on potential organizations to approach, in either a partnership or user capacity. For organizations seeking to expand their operations internationally, the FPQI helps provide insights on the IP capacity and capabilities of multiple jurisdictions worldwide, together with insights on the leading jurisdictions for specific technical domains.

More broadly, the importance of patents as an indicator of firm financial performance is reflected by the fact that Ding et al. [40] employed granted patents as the primary measure

[4][Online]. Available: https://www.FinTechfutures.com/2021/03/core-banking-provider-technisys-buys-ai-chatbot-operator-kona/

of firm innovation and revealed strong evidence that FinTech innovation has a positive impact on the real economy. This article, by developing an index that facilitates analysis at a 1) country, 2) technical field, and 3) organization level provides great utility to any stakeholder seeking to better understand and further investigate the impact which patenting activities have on the real economy. This article, therefore, represents a significant basis for further article focused on the impact of patenting activity on national economies [97], [99].

Nevertheless, there are limitations to this article. To date, there is no uncontested approach and consensus in academic research or among practitioners on evaluating the quality of a patent. As a result, it has been challenging to establish an accurate metric for the quality of a patent, as most metrics have been subjective. Furthermore, while patent quality is essential, it is also worth noting that not every high-quality invention is patented [62]. Despite this, in this article, a great effort has been made to assemble the most relevant indicators from the existing literature to construct a customized FinTech quality index and examine patents in different jurisdictions, technical fields and leading organizations.

While this article aims to examine the existence of potential *associations* between the variables of our interest, establishing *causality* is beyond the focus of this article. Nevertheless, such correlations may constitute the first step for future article to further study the possible causality between the variables identified.

The authors believe that there are some significant avenues for future articles to build upon the contributions of this articles. Further articles exploring the utility of the FPQI to organizations involved in mergers and strategic alliance activities would be of value. Focusing on patenting strategies, a comparison of traditional banks (e.g., JP Morgan or Bank of America) versus large technology companies (e.g., Apple) and how they use internal and external resources to develop their patent strategies could be a valuable avenue for further article related to FinTech utilizing this index. Exploring country level differences in the propensity to report information in patent applications (e.g., USPTO patents are more likely to exhibit a wider range of backward citations) would add further understanding of variation in jurisdictional quality. Furthermore, exploring the quality of non-FinTech patents, their contribution to an organization's earnings, and their impact on a nation's real economy, represents an additional opportunity for future article.

## Appendices

### Appendix I
The Search String Applied for the FinTech Patents Search

| **Derwent innovations index** | |
|---|---|
| **Search string** | ((“financial*technology*” OR ” FinTech*” OR ”techfin” OR “fin*tech*” OR “financial* start*up*”) **AND** (“digital information*” OR “blockchain*” OR ”payment” OR ”IOT” OR ”cloud computing*” OR ”machine learning” OR” artificial intelligence*” OR ”augmented reality*” OR ”virtual reality* ”OR” smart contract*” OR ”financial inclusion“ OR ”alternative data” OR ”lending*” OR ”digital*asset*” OR ”distributed ledger* technology*” OR ” peer-to *lending” OR ”P2P” OR ”crypto*currency*” OR ”bitcoin” OR ”crowdfunding*” OR ”digital payment*” OR ”digital payment*” OR ”robo-advising*” OR” digital tax*” OR ”taxation*” OR ”digital wallet” OR ” tokenisation*” OR ”initial coin offering*” OR ”token*” OR ”fintech nudges*”)) |

### Appendix II
Correlation Analysis

| | **Patent Quality** |
|---|---|
| **Claims counts** | 0.047*** |
| **Backward citation** | 0.958*** |
| **NPL** | 0.705*** |
| **Forward citation** | 0.280*** |
| **Family size** | 0.255*** |
| **IPC classification** | 0.085*** |

*$p \leq 0.1$; **$p \leq 0.05$; ***$p \leq 0.01$

Note: NPL stands for nonpatent citation; IPC stands for International Patent Classification.

## APPENDIX III
WEIGHTS OF EACH INDICATOR

| Indicators | Weights |
|---|---|
| **Claims count** | 4 |
| **Backward citation** | 34 |
| **NPL** | 41 |
| **Forward citation** | 11 |
| **Family** | 6 |
| **IPC classification** | 4 |
| **Sum** | 100 |

Note: NPL stands for non-patent citation; IPC stands for International Patent Classification.

## APPENDIX IV
COMPANY DETAILS AND RELATED INFORMATION REGARDING PATENT COUNT, REVENUE, AND EBIDITA

| *No* | *Company's name* | *FinTech patent count* | *Ln (Average revenue)* | *Ln (Average EBITDA)* | *Ln (Average patent quality)* |
|---|---|---|---|---|---|
| *1* | *Samsung Electronics Co. Ltd* | 353 | 11.83188 | 10.36725 | 1.423715 |
| *2* | *Apple Inc.* | 113 | 11.66409 | 10.5407 | 2.806798 |
| *3* | *IBM CORP* | 204 | 11.40889 | 9.883884 | 2.018173 |
| *4* | *Siemens AG* | 102 | 11.40349 | 9.228838 | 0.9243811 |
| *5* | *HITACHI LTD* | 37 | 11.39505 | 9.05797 | 0.8254786 |
| *6* | *Amazon Technologies Inc.* | 91 | 11.36448 | 8.973002 | 3.060343 |
| *7* | *Sony Corporation* | 76 | 11.19803 | 8.947422 | 1.232283 |
| *8* | *MICROSOFT CORP* | 330 | 11.16201 | 10.27037 | 2.336608 |
| *9* | *Google Inc.* | 259 | 10.89309 | 9.768003 | 2.515943 |
| *10* | *LG ELECTRONICS INC.* | 31 | 10.77203 | 8.259086 | 1.117626 |
| *11* | *FUJITSU LIMITED* | 27 | 10.69477 | 8.206979 | 3.665844 |
| *12* | *Nokia Corporation* | 60 | 10.49961 | 8.547305 | 2.291943 |
| *13* | *Facebook Inc.* | 50 | 10.07092 | 9.525735 | 1.44254 |
| *14* | *Alibaba Group Holding Limited* | 84 | 9.98552 | 8.903728 | 1.007693 |
| *15* | *KT CORPORATION* | 29 | 9.815358 | 8.418301 | 0.4463466 |
| *16* | *SAP SE* | 32 | 9.78206 | 8.598887 | 1.856558 |
| *17* | *Qualcomm Inc.* | 88 | 9.579633 | 8.471087 | 2.079149 |
| *18* | *PayPal Inc.* | 246 | 9.265878 | 7.883989 | 2.434358 |
| *19* | *FUJI ELECTRIC CO LTD* | 16 | 8.960217 | 6.230088 | 1.73596 |
| *20* | *EBAY INC.* | 102 | 8.923738 | 7.786344 | 2.195714 |
| *21* | *NCR Corporation* | 54 | 8.652738 | 6.416765 | 1.644496 |
| *22* | *Salesforce.com inc.* | 19 | 8.252342 | 6.150987 | 2.71866 |
| *23* | *Intuit Inc.* | 72 | 8.18883 | 7.05819 | 1.543741 |
| *24* | *Square Inc.* | 43 | 7.901229 | 5.149992 | 2.65964 |
| *25* | *Gemalto SA* | 43 | 7.733631 | 5.897154 | 1.168165 |
| *26* | *Aisino Corporation* | 10 | 7.544993 | 5.472523 | 0.3653373 |
| *27* | *SANKYO CO LTD* | 96 | 7.316276 | 5.953425 | 0.9827805 |
| *28* | *INGENICO GROUP* | 9 | 7.269477 | 5.525493 | 2.082562 |
| *29* | *Akamai Technologies Inc.* | 23 | 7.193565 | 6.258567 | 1.878625 |
| *30* | *HEIWA CORP* | 14 | 7.020334 | 5.454081 | 0.3390197 |
| *31* | *CUBIC CORPORATION* | 12 | 6.946072 | 4.45725 | 1.849635 |
| *32* | *DAIKOKU DENKI CO LTD* | 19 | 6.029699 | 3.829511 | 0.2796237 |
| *33* | *Alcatel-Lucent USA Inc.* | 22 | 5.123964 | 2.190536 | 1.533826 |
| *34* | *KONA I CO. LTD.* | 23 | 4.398146 | 2.704711 | 0.8020016 |
| *35* | MASTERCARD INTERNATIONAL INC | 1229 | 8.897136 | 8.242494 | 1.410465 |
| *36* | CANON INC | 14 | 10.43581 | 8.713066 | 1.196733 |
| *37* | Visa International Service Association | 349 | 9.320091 | 8.873468 | 3.344776 |

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