

# Patent Enforcement Across 51 Countries

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# Patent enforcement across 51 countries – Patent enforcement index 1998–2017



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### ABSTRACT

Indices are central for comparing the strength of patent systems across countries in international business research, intellectual property management and policymaking. However, existing approaches rely on book laws while most variance across countries emerges from enforcement. We address this weakness and present the Patent Enforcement Index which tracks differences in patent enforcement for 51 countries between 1998 and 2017. We utilize novel firm-level enforcement data and extend the conceptual framework of the patent systems strength index provided by Papageorgiadis et al. (2014). The new index reveals previously uncaptured volatility in patent enforcement and can be decomposed into three topical sub-indices.

# 1. Introduction

Countries differ widely in the degree to which legal institutions allow innovative firms to capture economic value from new products or technologies based on effective and efficient enforcement of intellectual property rights (Teece, 1998). Such differences in the strength of national patent and intellectual property (IP) protection systems are a major theme in international business literature for explaining (a) the location and nature of technology development across countries (Lamin & Ramos, 2016; Zhao, 2006) as well as (b) how changes in patent systems affect firm decisions particularly in emerging economies (Brander, Cui, & Vertinsky, 2017; Brandl, Darendeli, & Mudambi, 2019; Peng, Ahlstrom, Carraher, & Shi, 2017a). Given the importance of patent systems for research in international business, research lacks an instrument that allows us to not just compare differences in IP book laws across countries but tracks patent enforcement specifically as a separate dimension of patent systems (notable exceptions include Papageorgiadis, Cross, & Alexiou, 2014).

The goals of this study are therefore twofold. First, we provide researchers with an up to date index on the strengths of patent enforcement for capturing differences in enforcement for a large number of countries as well as their dynamics over time. This index can complement other indices tracking IP book laws independently of their enforcement (e.g. Park, 2008). Second, we decompose the overall index into sub-indices (such as the monitoring costs for potential infringement) that can be used for testing precise theoretical predictions on the effects of patent enforcement going beyond strong/weak comparisons. For this purpose, we utilize the conceptual framework of the index of Patent Systems Strength (PSS) published by Papageorgiadis et al. (2014). We extend this framework by incorporating newly available firm-level patent litigation data with broad country coverage. By integrating such patent litigation data into the PSS framework, we obtain a new index that does not merely proxy differences in patent system strengths in general but patent enforcement in particular. In this sense, we present a new Patent Enforcement Index (PEI) covering 51 countries between 1998 and 2017.

We reason that the Patent Enforcement Index addresses a gap in the existing toolbox of research in international business. Given that patent systems emerge from a multitude of laws, treaties, regulations or court decisions, research has relied mostly on fundamental changes such as the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement of the Word Trade Organization (WTO) (Kyle & McGahan, 2012) or used indices condensing information based on IP book laws across countries (Ginarte & Park, 1997; Park, 2008). These approaches would lead us to believe that when a country adopts certain patent laws they are immediately and uniformly applied by its agencies, courts, police and customs organizations. However, a major source of differences and dynamism in the strength of patent systems originates from the degree to which patents do not just confer rights to their holders but how effectively and efficiently they can be enforced. The effectiveness of the enforcement aspect is either not an obligatory part of treaties, e.g. in the case of TRIPS (Papageorgiadis & McDonald, 2019), or indices

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(and researchers using them) assume that published laws and their level of enforcement overlap (Ginarte & Park, 1997). However, recent research suggests that firms are very much aware of differences in patent enforcement across countries and adjust their IP strategies (Beukel & Zhao, 2018; Brander et al., 2017). Accordingly, an index is required that captures patent enforcement differences separately but in combination with indices tracing patent laws on the books.

The Patent Enforcement Index partly reconceptualizes and expands the PSS index and its transaction cost framework to measure the strength of enforcement related components of national patent systems. The framework provides the most comprehensive contextual coverage of the enforcement aspects of patent systems (Papageorgiadis & McDonald, 2019). While the PSS index condenses country-level data, it is likely to underestimate the private information about international patent enforcement that underlies firm level litigation decisions. Private information emerges from the individual experiences and local knowledge sources of patent lawyers and managers based on past enforcement experiences which allows them to judge enforcement aspects such as the length of patent litigations or the odds of success. They incorporate this information in their individual litigation decisions. Such comprehensive information on firm's international patent litigation has become recently available through Darts-IP (introduced by Beukel & Zhao, 2018). We exploit the data opportunity for establishing the Patent Enforcement Index. For decomposing the information content from the available litigation data, we engage in a recursive, threestage validation exercise engaging a total of 52 IP experts such as patent councillors, patent lawyers, consultants and managers.

The index presented in this study enables academic research and IP decision making in practice along two dimensions. First, a large stream of research acknowledges that the strength of patent protection in countries is dynamic over time (Peng et al., 2017a; Peng, Ahlstrom, Carraher, & Shi, 2017b) and that patent laws and their enforcement often times diverge particularly in emerging economies (Brander et al., 2017). While many theoretical or qualitative studies highlight that the strengths of patent systems depends on both law and enforcement components (e.g. Keupp, Beckenbauer, & Gassmann, 2009), the enforcement aspect has so far been elusive to measure across countries. A prominent example is the use of the TRIPS agreement in empirical studies. TRIPS does not include provisions that oblige member countries to effectively enforce patent law in practice (Papageorgiadis & McDonald, 2019) and the same TRIPS instigated laws and regulations can be interpreted or enforced differently by the judiciary of different countries (Khoury, Cuervo-Cazurra, & Dau, 2014). Measurements of patent strength ignoring enforcement are therefore likely to lead to biased results or spurious empirical findings, e.g. on the location choices of global R&D centers. Such measures are likely to overestimate the strengths of the patent system in cases in which countries adopt more stringent IP laws or treaties without updating enforcement opportunities and instruments. Similarly, the strength of patent systems in countries upgrading the opportunities for detecting and punishing patent infringement is likely to be systematically underestimated when countries do not change laws at the same time. Hence, PEI enables new theorizing and empirical testing in models relying on patent enforcement related uncertainties which are central to many core international business theories such as transaction cost economic models of internationalization, location choices for FDI and R&D, or informal institutions and their consequences.

Second, the PEI index presented in this study decomposes the overall strengths of patent enforcement into sub-indices measuring servicing, protection and monitoring components, i.e. the theoretical components of the enforcement framework identified by Papageorgiadis et al. (2014). These sub-indices are the scores for the servicing costs construct (e.g. the ease of patent administration), the property rights protection costs construct (e.g. the efficiency of courts and law enforcement for effectively punishing infringement) and the monitoring costs construct (e.g. the availability of data for identifying

infringement). The ability of measuring each component individually but comparably across countries, enables researchers to go beyond strong/weak comparisons and test precise theoretical relationships. On the one hand, research explaining the evolution of patent systems and its drivers (e.g. Brandl et al., 2019) can disentangle changes in patent enforcement or explore interactions between components. On the other hand, our index provides opportunities for studying which components of a country's patent system influence firm level decisions, e.g. on the type of technology being developed in certain locations (e.g. Zhao, 2006) or which safeguards against misappropriation need to be put in place (e.g. Lamin & Ramos, 2016).

We demonstrate the usefulness of the PEI index for research and practice by describing examples of noteworthy trends in patent enforcement that the index captures (see Section 4 for an extended description). These include how (a) countries such as Argentina or Indonesia have increased the strength of their patent book laws by adopting TRIPS while patent enforcement remains weak, (b) countries such as the UK and Romania have increased the strength of patent enforcement even without adjusting book laws and (c) the increase in the overall strength of patent enforcement in countries such as the UK can be traced back to improved monitoring of potential patent infringement (monitoring sub-index), not legal enforcement in courts per se.

In the next section we review the three constructs that comprise the transaction cost framework for patent enforcement (Papageorgiadis et al., 2014) and describe the extension with additional, firm level litigation data. Section 3 presents the calculation of the PEI index and the disaggregated sub-index scores. Section 4 provides a discussion of illustrative findings and trends. Section 5 provides the conclusions of the study.

# 2. Review of the transaction cost components of patent enforcement and the creation of the Patent Enforcement Index

## 2.1. Transaction costs originating from patent enforcement

Papageorgiadis et al. (2014) conceptualize patent enforcement based on the perceived levels of transaction costs that patent owning firms can expect to confront when engaging with and enforcing their rights in the patent system of a country.<sup>1</sup> Firms experience three types of transaction costs when engaging with the patent system of a country: servicing costs, property rights protection costs, and monitoring costs. Patent councillors and managers of firms face high transaction costs in countries where the enforcement of patent rights is ineffective and/or inefficient for the IP owning firm. Papageorgiadis et al. (2014) use country level data to create a composite index of the three transaction cost components to calculate an index of patent systems strength (PSS). The three constructs can be summarized as follows (Table 1 provides a complete list of index items and data sources respectively):

### - Servicing costs

The servicing costs construct measures the transaction costs that patent owners face depending on the quality of the patent administration in a country. The PSS index includes proxies that measure the quality of patent administration in terms of: a) the "efficiency, transparency and timeliness of agencies that deal with patent-related matters and their systems and routines" and b) "the quality of administrative

<sup>&</sup>lt;sup>1</sup> The PSS index follows a patent owner's perspective in the measurement of the perceived levels of transaction costs that patent owners face in a country. As highlighted in Papageorgiadis et al. (2014), while low levels of transaction costs in a country may be desirable conditions for patent owners, this may not necessarily be the most desirable or appropriate conditions for the country overall.

Transaction costs originating from the patent system and proxies used to calculate the new PEI index.

Cost Type	Component of the Patent System	Data and Sources
Servicing Costs	Quality of patent administration	Bureaucracy quality index (ICRG)
		"Bureaucracy does not hinder business activity" (WCY)
	*Complexity, clarity & communication of patent related regulations & procedures	Darts-IP
Property Rights Protection Costs	Judicial enforcement	"Judicial independence" (GCR)
		"Law and order" (ICRG)
		"Justice is fairly administered" (WCY)
	*Upholding of patent rights in courts	Darts-IP
	Level of corruption in judiciary	Corruption perceptions index (Transparency International)
Monitoring Costs	Effectiveness of police enforcement	Country listings from the Special 301 Report (United States Trade
	Strength of border controls	Representative) (USTR)
	*Opportunistic activities of Non Practicing Entities	Darts-IP
	Positive/negative perceptions of patent owners about national patent	Intellectual property rights (WCY)
	protection and enforcement levels	Intellectual property protection (GCR)
	Cultural and societal attitudes towards the purchase of infringing goods	Global PC software piracy (BSA)
	Level of public commitment to patent protection	

\* indicates a new enforcement component of patent systems that is included in the PEI index but was not included in the Papageorgiadis et al. (2014) index.

decisions made by government agencies who deal with patent related matters for and on behalf of foreign and domestic firms" (Papageorgiadis et al., 2014, p. 589).

### - Property rights protection costs

The property rights protection costs construct measures: a) "whether or not ownership rights are upheld by the patent system" and b) "the general effectiveness of the judiciary, police forces, customs officials and other government agencies when undertaking patent enforcement-related activities" (Papageorgiadis et al., 2014, p. 589). The construct is originally measured for PSS with four variables, three that proxy for the effectiveness of judicial enforcement and one that proxies the level of corruption in the judiciary.

- Monitoring costs

The monitoring costs construct measures the transaction costs that firms face for monitoring IP use by competitors and for constraining opportunistic actions. The construct is measured with five proxies that capture the effectiveness of police and customs control, the perceptions of patent owners about the effectiveness of patent enforcement, and the cultural, societal attitudes and the public's commitment towards patent protection (Papageorgiadis et al., 2014, p. 589).

### 2.2. Creation of the patent enforcement index

We create the Patent Enforcement Index by extending the PSS framework and incorporating information about patent litigation decisions of firms across countries. The PEI is a significant extension of the PSS index since it measures not merely general strength of a patent system but more specifically patent enforcement by incorporating firmlevel litigation decisions and outcomes. While such data has been available for individual countries before, we gain access to the most comprehensive international patent litigation dataset of the commercial company Darts-IP and hand collect data on patent litigation per country.

Darts-IP is widely used by patent councillors and IP managers but has only recently been introduced to the international business literature by Beukel and Zhao (2018). Darts-IP collects data on IP litigation from 3571 courts in 119 countries, offering access to over 1.5 million patent litigation cases to date (Darts-IP, 2019a). More than 30,000 practitioners subscribe to the database, including global firms such as Siemens, Philips, Novartis, ZTE as well as international and national organizations such as the European Patent Office and the Korean Intellectual Property Office (Darts-IP, 2019b). Darts-IP provides the most comprehensive patent litigation dataset and has been previously used in studies that assess the effect of patent litigation across more than one countries, such as Beukel and Zhao (2018) and Cremers et al. (2017).

Aggregated patent litigation data based on the litigation decisions of individual firms across countries is a useful extension of the PSS index since it provides detailed information about each patent litigation activity that plaintiffs file in 112 countries. The information include the date and location of a litigation case, the parties involved, the type of litigation (e.g. patent infringement, patent opposition), the stage in the litigation process and outcome of a litigation (if decided) as well as access to the full text of each litigation case. Patent managers accessing this information can uncover important insights about the litigation strategy of competitors or of firms operating in the same industry. Such information include the success rate of patent litigation for plaintiffs in different countries, the way that a firm articulates and crafts the argumentation in their litigation case (recipe for success), and the type of patent litigation that a firm regularly undertakes in specific countries (e.g. infringement). Accessing such information at the aggregate level is a valuable data source which goes well beyond the country-level data entering the PSS index. Accordingly, the availability of such litigation data enables us to create the PEI index which is consistent with the transaction costs components of PSS but specifically focusing on realized patent enforcement activities across countries. Naturally, patent litigation data reflects outcomes from considerations about the enforceability of patent rights in a given country but does not immediately reveal the considerations that went into the decision to litigate in a particular country or not.

For unlocking the informational content of patent litigation, we follow an iterative, three stage process of recursively involving decisions makers on patent enforcement such as patent lawyers, counselors and managers. The purpose of this exercise is to (a) understand the data items from the international patent database that best capture aspects of patent enforceability at the country level and (b) validate their incorporation in the PEI index.

In the first stage of the validation exercise, we conduct six in-depth, open ended interviews with IP managers and patent lawyers at leading IP conferences across Europe (see Table 2 for details). The goal of this stage is to uncover which items of the patent litigation data are relevant for decision makers assessing patent enforceability in a country and how they interpret the available information, e.g. the access to litigation exercise, we contrast these qualitative insights with the patent enforcement literature. We incorporate the interview input into transaction cost components of Papageorgiadis et al. (2014) and calculate a prototype of the PEI index (please see Section 3 for details on the calculation).

resentations of the PSS and extended PEI index at	policy making	g and practitioner confe	rences during 2015-2018.
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Stage one of the validation process	Stage three of the validation process
Presentations and individual discussions at practitioner conferences enabling the creation of a prototype for the extension of the PSS index	Expert discussion as part of practitioner conferences enabling the validation of the prototype of the extended PEI index
<ol> <li>European Patent Office's (EPO) annual "PATLIB17" conference (keynote), Munich, 3-4 May 2017.</li> </ol>	1. "IP Law Europe Summit 2018", Montreux, 21 – 22 June 2018.
2. "IP World Summit 2017", Amsterdam, 25-27 September 2017.	2. "IP world Summit 2018", Amsterdam, 9-10 October 2018.
3. "Global Patent Congress", Brussels, 26-28 September 2016.	3. "Brand Protection Excellence Forum", Munich, 7-8 June 2018.
4. "Pat-Tech Strategy Exchange" conference, Dublin, 14-15 June 2016.	4. "Nordic IPR conference", Copenhagen, 10-11 April, 2018.
5. "Nordic IPR" conference, Copenhagen, 14-16 March 2016.	
6. "Global Patent Strategy Exchange" conference, Dublin, 09-10 June 2015.	

In stage three of the validation process, we present the prototype of the PEI index to large groups of IP experts at four practitioner conferences and workshops in 2018, encouraging broader feedback on the interpretation of newly added data and reflections on the validity of the index as a whole (Table 2). With each round of feedback, we return to literature and index calculation for improving the index until the process reaches saturation.<sup>2</sup>

As a result of the process, the Patent Enforcement Index emerges as an extension of PSS along all three transaction cost constructs. We highlight these extensions based on firm-level data since they constitute the distinct advantages for PEI:

### - Servicing costs

Servicing costs can arise from the complexity, clarity and frequency of communication of patent related regulations and processes. PEI extends the PSS framework by capturing such servicing costs using data on the number of patent litigation cases filed in a country using data from the Darts-IP dataset of global patent litigation. Following our validation exercise, rich records of previous patent litigation enable patent/IP councillors to gain a better understanding of how other firms interpret regulations in a country and develop their litigation strategies accordingly. Put differently, countries with few preceding litigation cases are opaque and unpredictable. Past litigation cases provide a rich source of information and the availability of a large number of past litigations allows patent managers to analyze this information and learn details about the functioning and quality of patent administration in a country. Litigation cases can reveal important information about the speed with which patent litigation cases are administered in a country as well as the type and quality of experience of patent administration. Content analysis of previous patent litigations can help patent owners to identify e.g. patterns in the case development and important details on the development and outcomes of patent litigation cases that can increase the chances of success. This can a priori reduce the servicing costs that patent owners will face before even investing in a country and confidently develop a litigation strategy or plans for how to approach litigation, before an infringement incident (Darts-IP, 2018). The count of patent litigations can introduce bias to the index since it would artificially inflate index values for countries with extreme values, especially the US. We therefore transform the data into a logarithmic (log) scale that reduces skewness and is better suited to reflect differences

<sup>2</sup> There were two main discoveries and adjustments made. First, there are few studies in the patent enforcement literature that focus on the effect of patent trolling activities on firm behaviour. The feedback process confirmed that patent trolling activity is an important enforcement related aspect of national patent systems and verified the rationale and approach of incorporating the data in the monitoring costs construct. Second, the existing patent enforcement literature does not capture the practice of IP managers and patent lawyers in extracting and using information content from past patent litigation cases. The feedback process confirmed the importance of the information content in patent litigation cases and verified its relevance to the servicing costs construct.

across countries.<sup>3</sup> Higher scores indicate countries where servicing costs are low and patent owners are able to analyse many patent litigation records.

### - Property rights protection costs

PEI captures the property rights protection costs that firms face in a patent system of a country depending on the extent to which their ownership rights are upheld in courts. This measurement is absent in the PSS index. More precisely, we use the percentage of patent cases won by plaintiff patent owners in a country annually following the approach of Elmer and Gramenopoulos (2018) and utilizing the Darts-IP database (2019a). Following the validation exercise, higher shares of successful lawsuits for plaintiffs in a country indicate comparatively lower property rights protection costs for patent owners. This is because higher rates of successful patent lawsuits for plaintiffs indicate a favourable environment for patent enforcement, in which patent owners can anticipate that their enforcement actions will be positively received by the judiciary and successfully upheld in courts (Elmer & Gramenopoulos, 2018)

- Monitoring costs

PEI extends the measurement of monitoring costs by taking into consideration the monitoring costs that patent owners experience in a country from the activity of Non-Practicing Entities (NPEs), often referred to as "patent trolls" (Darts-IP, 2018). Following Darts-IP (2018, p. 18) NPEs are defined as "independent organizations (legal entities) which own or benefit from patent rights but do not sell or manufacture goods or services associated with them (i.e., non-operating companies) and which have an active (offensive) assertion or litigation role as plaintiffs towards the enforcement of their patent rights". Patent trolls are frequently accused of using predatory patent lawsuits against firms, often forcing the defendants to sign a licensing agreement in order to avoid the transaction costs of engaging in lengthy and costly lawsuits which threaten especially young or small firms (Stoll, 2014). As indicated by patent experts during the validation exercise, patent owners face substantial transaction costs when engaging in monitoring activities for defending their rights and fend off opportunistic behaviour of patent trolls in a country. In countries where patent trolling activity is high, firms require complex patenting approaches. The risk from patent troll litigation forces firms to develop costly patent thickets by

<sup>&</sup>lt;sup>3</sup> We would like to thank one anonymous reviewer for suggesting the use of a logarithmic scale. Previous versions of this variable transformed the data in a categorical scale with values ranging from 1 to 4. We assigned a minimum score of 1 to countries with no or just one reported patent litigation case for a given year. Countries with 2 to 50 patent litigation cases filed received a score of 2 and countries with 51-250 patent litigations filings received a score of 3. Countries with 251 + patent litigation filings received the maximum score of 4. The results of the categorical variable have a .99 correlation with the results from the logarithmic variable and the country scores are almost identical.

inventing and patenting around core technologies (Somaya, 2012). Firms may also need to undertake larger scale patent monitoring activities to identify vulnerable patents. Further, the threat from patent trolls forces firms to analyse patent portfolios of patent trolls and proactively litigate to challenge the validity and enforceability of the patents owned by the patent troll entity (Somaya, 2012). Finally, patent owners can also potentially invest in patent litigation insurance (especially in the US) (EUIPO, 2018) and engage with industry coalitions and undertake political lobbying activities to limit the scope of patent troll litigation. Accordingly, low levels of patent troll litigation in a country indicate comparatively lower levels of monitoring costs. Given that the count number of patent trolling litigation activities can introduce bias to the index since it would disproportionally affect countries with extreme values such as the US, we transform the data into a log scale (similar to the count number of patent litigations in the servicing costs construct).<sup>4</sup> We reverse the scale, since high numbers of NPE patent litigation cases are increasing the monitoring costs that firms face in a country.

Table 1 provides the full overview of firm-level litigation data entering the PEI index. For consistency with the transaction cost framework of Papageorgiadis et al. (2014), we include the original variables and data sources of the PSS index. Using this extended set of data, we calculate the PEI index and report the results in the next section.

### 3. Results of the patent enforcement index 1998-2017

We follow the methodological approach suggested by Papageorgiadis et al. (2014, p. 591-593) for consistency with PSS and calculate PEI. This approach starts with normalizing the data using zscores. Next, we apply two multivariate analysis tests, Cronbach's alpha and factor analysis to evaluate the internal consistency of each of the three transaction costs constructs that comprise the overall PEI. The Cronbach's alpha scores are 0.87 for the property rights protection costs construct, 0.82 for the monitoring costs construct, and 0.54 for the servicing costs construct. The scores for the monitoring cost and property rights protection cost scores are higher than the 0.70 threshold (Nunnally, 1978), indicating high internal consistency of the variables used to calculate the two constructs. The score of the servicing costs construct however is lower but still at an acceptable level above 0.50, demonstrating moderate reliability (Hinton, McMurray, & Brownlow, 2004). The low score of the servicing construct is not unusual given that the fewer the variables in a construct, the more difficult it is for the scores to be high (Miller, 1995). The application of factor analysis related tests enables us to confirm that the level of internal consistency of the servicing costs construct is moderate but appropriate (Miller, 1995).

We carry out the Bartlett test of sphericity to evaluate if the correlation matrix is not identical and that there are sufficient correlations between the included variables to calculate an index (Hair, Anderson, Tatham, & Black, 2009). The results for all three constructs are significant at the 99 % level and well above the customarily applied significance level of 95 %. We also apply the KMO test to evaluate the adequacy of the sample size of the constructs and find that the scores are 0.83 for the property rights protection costs construct, 0.81 for the monitoring costs construct, and 0.56 for the servicing costs construct. The KMO scores of all three constructs are higher than the minimum acceptable level of 0.5. The factor analysis tests therefore reveal that while the internal consistency score of the servicing costs construct is relatively moderate, the sample size and correlations between the variables are sufficient for calculating an index for this construct.

As in Papageorgiadis et al. (2014), we calculate a single numerical value score for each of the three constructs using the weighting scheme derived from factor analysis. It is important to highlight that "factor analysis intervenes only to correct for overlapping information between two or more correlated indicators, and is not a measure of the theoretical importance of the associated indicator." (OECD, 2008, p. 89; Papageorgiadis et al., 2014, p. 592). We calculate the index score of each of the three constructs (disaggregated sub-indices) using the "total variance explained" results of the factor analysis. To calculate the composite index score of the monitoring cost construct index, the statistical weight allocated to the WEF IP protection variable is 65.5 %, the IMD IPR variable 20 %, the BSA piracy rates variable 8.5 %, the USTR Special 301 Report variable 4%, and the NPE litigation activity variable 2%. The weighting for the property rights protection costs construct index is 70 % to the CPI variable, 19 % to the WEF variable, 7% to the IMD judicial independence variable, 2% to the ICRG law and order variable, and 2% to the win rates for patent owners variable. Finally, the weights for the servicing costs construct are 55 % to the ICRG bureaucracy variable, 34 % to the IMD bureaucracy variable, and 11 % to the patent litigation activity variable. Overall, the composite index scores of the servicing costs construct are reported in Table 3 below, while Table 4 reports the scores of the property rights protection costs construct, and the scores of the monitoring costs construct are reported in Table 5.

Finally, we calculate the overall composite PEI index by allocating equal weights to the scores of each of the three transaction costs constructs. For conceptual reasons, we do not use factor analysis for this formative construct and we do not force the factor analysis to generate orthogonal sub-indices. Indeed, it is likely that countries in which patent enforcement is a low priority may for example tolerate both inefficient patent administration (servicing costs) as well as opaque systems for potential patent infringement (monitoring costs). However we follow the theory based conceptual framework (as discussed in Section 2) which shows that the transaction costs constructs measure distinctive elements of the enforcement related aspects of patent systems. Therefore correcting for overlapping information between the three constructs is not required (OECD, 2008, p. 89). Table 6 reports the scores of the overall PEI index, and Fig. 1 reports the score of PEI for the year 2017, together with each of the component scores for each country.<sup>5</sup> Each of the Tables 3–6 provides the full data for all countries across the entire time period 1998-2017. Higher scores (maximum of 10) indicate strong patent enforcement systems in which patent owners anticipate to experience low levels of transaction costs from enforcement. In contrast, low scores indicate countries where patent owners anticipate high levels of transaction costs when enforcing patent rights. The mean score for all countries in the entire 20-year time period is 5.8 with a standard deviation of 2.3. The lowest score is 0.1 for Venezuela in the year 2014 and the highest score is 9.7 for Finland in the years 2000 and 2001.

# 4. Important trends in the Patent Enforcement Index between 1998–2017

We use the results from the PEI index for highlighting four

<sup>&</sup>lt;sup>4</sup>We would like to thank one anonymous reviewer for suggesting the use of a logarithmic scale for this variable. Previous versions of this variable transformed the data in a categorical scale with values ranging from 1 to 4. We assigned a minimum score of 1 to countries where there were more than 250 patent troll litigation cases per year, indicating higher levels of monitoring costs for the patent owning firm. A score of 2 was awarded to countries where the number of patent troll related litigation cases per year ranged from 50 to 250, and a score of 3 to countries with more than one patent troll related case filed per year. A score of 4 was assigned to countries where there were no identified patent trolling litigation cases in a particular year. The results of the categorical variable have a .99 correlation with the results from the logarithmic variable and the country scores are almost identical.

<sup>&</sup>lt;sup>5</sup> The scores for the US in the index of the monitoring costs construct are calculated without the use of the USTR301 variable. This is because the US Trade Representative 301 Report provides an assessment of foreign (to the US) patent systems but not an assessment of the US patent system. The weight is equally distributed to all other variables.

Index scores of servicing costs construct.

Country	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Argentina	5.6	5.5	5.1	5.2	4.5	4.5	4.4	4.5	4.7	4.4	4.6	4.2	4.5	4.4	4.4	4.6	4.2	4.5	5.3	4.9
Australia	8.6	8.7	8.7	8.7	8.7	8.6	8.8	8.1	8.2	8.4	8.6	8.5	8.2	8.6	8.3	8.0	8.5	8.1	8.3	7.9
Austria	6.9	7.5	7.7	8.1	8.1	7.7	8.2	8.1	8.2	8.3	7.9	7.3	7.5	7.4	7.5	7.2	7.0	6.2	6.3	6.5
Belgium	6.8	6.8	6.9	6.8	6.9	6.7	6.6	6.5	6.6	6.8	6.7	6.4	6.6	6.7	6.7	6.6	6.6	6.9	7.3	7.1
Brazil	3.9	3.4	39	3.6	37	3.6	3.1	3.0	3.0	2.9	2.7	3.3	2.7	3.1	3.0	2.8	2.5	2.5	2.5	2.5
Canada	8.6	8.6	8.6	8.5	8.4	81	87	8.3	8.6	8.4	8.6	8.3	81	8.9	8.6	8.9	87	9.0	8.6	8.5
Chile	5.6	5.9	6.0	5.7	5.8	6.0	6.2	6.3	6.2	5.5	5.7	5.3	5.3	6.3	6.9	61	6.0	5.5	5.3	5.3
China	5.2	49	5.1	5.4	61	6.1	53	5.6	6.1	6.2	6.2	5.4	5.7	5.9	4 1	4.0	41	4.0	43	47
Colombia	2.6	2.5	2.6	2.8	29	3.4	35	2.8	3.4	3.2	33	27	27	3.4	27	2.8	2.8	2.6	2.6	24
Czech Republic	5.2	4.8	4.0	4.0	5.2	4 9	47	5.1	53	47	5.1	5.0	53	5.5	5.0	4.8	5.1	5.1	5.2	5.0
Denmark	0.2	0.1	9.0	9.5	0.0	9.9	ч./ О./	8.6	0.5	0.2	0.1	8.0	9.J	85	0.0	9.0	8.6	8.2	9.2	9.0
Ectopia	9.2	9.1	9.0	5.5 E 2	9.0 1 Q	0.0 E 4	5.4	5.0	5.5	5.5	5.1	4 5	5.4 E 2	5.5 E 0	5.0 E 7	0.0 E E	5.0	5.2 E 0	0.0 E 2	5.0 E 2
Estolild	_ 0 E	-	- 0.7	0.5	4.0	0.4	0.0	0.1	0.6	0.0	0.4	4.5	0.0	0.0	0.2	0.2	0.2	0.4	0.5 0 E	0.5
Fillidilu	9.5	9.9	9.7	9.5	9.0	9.0	9.5	9.1	9.0	0.3 E 6	0.5	9.2	9.2	9.2	9.3	9.5	9.5	0.4	0.0 F 1	0.7
Component	7.4	7.4	7.5	0.4	5.0	5.0	5.9	0.0	5.9	5.0	5.7	5.9	5.7	0.4	0.0	5.0	0.0	0.1	0.1	0.0
Germany	7.9	/./	0.4	0.4	/./	1.2	/.3	7.4	/./	7.8	/./	8.0	/.8	0.4	0.0	8.0	8.0	0.1	8.4 4.0	8.3
Greece	4.4	4.5	8.4	4.8	4.5	4.3	4.3	4.2	4.3	4.6	4.3	4.0	4.1	4.0	3.9	4.5	4.1	4.2	4.0	3.9
Hong Kong	7.5	7.2	7.2	7.0	6.6	7.0	6.7	6.8	7.5	7.2	6.8	6.5	5.9	6.7	7.6	7.0	6.5	7.1	7.4	7.1
Hungary	7.4	7.5	7.6	7.1	7.3	7.3	5.5	5.0	5.1	5.2	4.9	4.5	4.1	4.7	4.5	4.4	4.6	4.3	4.2	4.6
Iceland	8.8	8.3	8.9	9.0	8.9	9.5	9.1	9.0	9.3	9.5	9.5	9.5	7.5	7.7	7.8	7.9	7.9	7.8	8.0	8.2
India	5.4	4.8	5.3	5.0	5.1	5.1	5.5	5.4	5.8	5.5	5.7	5.6	5.6	5.7	5.6	5.5	5.6	5.6	6.2	5.8
Indonesia	3.2	4.1	4.8	3.2	3.3	2.6	2.5	2.7	2.7	2.8	3.4	2.8	3.1	3.2	3.5	3.6	3.5	3.2	3.9	3.7
Ireland	8.8	8.4	8.9	8.7	8.5	7.6	7.6	7.7	8.2	7.9	8.1	7.8	7.6	8.0	8.4	8.2	8.7	8.6	8.4	8.5
Israel	7.9	8.1	7.8	8.0	7.8	7.2	7.0	7.4	7.5	7.4	7.3	7.0	7.4	7.4	7.3	7.4	7.1	7.3	7.3	7.4
Italy	5.1	5.0	5.0	4.8	4.2	4.6	4.4	4.3	4.2	4.1	4.0	4.1	4.2	4.0	4.3	3.8	3.7	3.7	4.2	4.0
Japan	7.0	7.4	7.7	7.4	7.6	7.5	7.6	7.7	8.0	8.0	7.6	7.5	8.2	7.9	8.3	8.4	8.4	8.4	8.5	8.5
Jordan	-	-	-	-	-	3.7	3.7	3.5	3.6	3.7	3.7	3.1	2.9	3.1	3.8	3.4	4.2	4.0	3.1	3.5
Korea (South)	4.9	4.9	5.4	5.8	5.7	5.7	5.7	5.9	6.1	5.9	4.9	5.1	5.5	5.8	5.9	6.6	5.4	5.5	5.1	5.3
Malaysia	6.2	5.9	6.1	5.4	6.2	6.6	6.3	5.4	6.4	6.2	5.7	5.4	6.6	6.4	6.9	6.3	6.7	6.5	6.0	6.2
Mexico	4.8	4.7	5.2	4.9	4.8	4.9	4.4	4.9	4.6	4.4	4.5	4.5	4.0	4.7	5.2	5.4	4.3	3.6	4.0	3.8
Netherlands	9.0	8.7	9.2	8.5	8.7	7.9	7.9	7.9	7.8	8.1	7.9	7.8	7.5	8.5	8.8	8.7	8.2	8.5	8.7	8.9
New Zealand	9.0	8.2	8.2	7.9	8.0	7.7	7.3	7.5	7.4	7.5	7.6	7.4	7.1	8.2	8.1	8.0	8.4	8.0	8.4	8.6
Norway	8.6	8.0	8.0	7.0	7.8	8.1	7.9	7.6	8.6	8.2	7.8	7.8	7.6	8.1	7.8	8.1	8.3	7.9	8.3	8.5
Philippines	5.1	4.7	4.7	4.5	4.5	4.7	4.5	4.4	4.3	4.4	4.1	4.1	4.3	4.4	4.9	4.9	5.0	4.6	4.3	4.8
Poland	4.1	4.6	5.2	4.4	4.1	4.3	4.2	4.0	3.9	3.8	4.2	4.1	4.1	4.3	4.6	5.4	4.5	4.9	5.0	4.7
Portugal	4.9	4.9	4.6	4.7	4.3	4.6	4.5	4.5	4.4	4.8	4.9	5.4	4.9	5.3	5.6	5.1	4.9	5.5	5.0	4.9
Romania	-	-	-	-	-	0.5	0.5	0.2	0.8	1.1	0.3	0.2	0.9	0.9	0.8	1.3	0.2	1.4	1.0	0.8
Russia	1.3	0.5	0.6	0.9	0.8	0.6	0.9	0.4	1.2	0.9	0.8	0.8	0.8	1.0	0.8	1.0	1.6	1.5	1.8	1.7
Singapore	9.5	9.8	10.0	9.4	9.8	9.2	8.9	9.4	9.3	9.7	9.4	8.7	8.9	8.8	9.5	9.1	8.8	9.4	9.5	9.5
Slovakia	-	-	-	4.3	4.2	4.5	5.0	5.0	5.1	5.0	4.9	4.9	4.6	4.4	4.5	4.3	4.4	4.4	5.1	4.6
Slovenia	-	4.4	4.5	4.3	4.6	4.7	4.5	4.4	4.6	4.7	4.8	5.1	4.3	4.2	4.3	4.1	4.2	4.2	5.2	5.7
South Africa	4.5	3.4	3.6	3.4	3.7	3.7	3.7	3.2	3.2	2.8	2.7	3.0	3.2	2.9	3.2	3.1	3.2	2.5	2.6	2.6
Spain	6.1	6.4	7.0	8.0	8.0	7.9	6.6	5.6	5.0	5.0	4.9	4.4	4.4	5.0	5.1	4.4	4.4	4.5	4.6	4.8
Sweden	8.7	8.3	8.9	9.0	9.0	8.6	8.5	8.2	8.2	7.7	8.2	8.2	8.0	9.1	8.9	8.9	8.7	8.2	8.5	8.4
Switzerland	9.0	9.1	9.2	9.0	9.2	9.1	8.5	8.6	8.6	9.2	8.8	8.6	8.9	9.2	9.4	9.1	9.4	9.0	9.2	9.1
Taiwan	6.0	6.0	5.9	5.8	6.0	5.8	6.2	6.1	6.1	6.3	6.4	6.1	6.7	6.6	6.9	6.6	6.7	6.6	6.5	6.7
Thailand	3.4	3.5	3.3	3.4	3.7	4.2	4.0	4.0	3.8	3.1	3.5	3.3	3.5	3.8	4.0	3.6	3.2	3.2	3.8	4.0
Turkey	3.3	3.3	3.4	2.9	2.9	2.7	2.8	3.2	3.1	3.2	3.2	3.4	3.3	4.0	3.9	4.3	3.9	3.5	3.6	3.7
USA	8.6	8.5	9.0	8.4	9.0	8.8	9.0	8.2	8.9	8.5	8.3	7.8	8.1	8.8	8.8	8.8	8.8	8.4	8.7	8.7
Ukraine	_	_	_	_	_	_	_	_	_	0.6	0.3	0.4	0.3	0.3	0.7	0.2	0.7	0.7	0.7	0.7
United Kingdom	8.4	8.0	8.3	7.6	7.4	7.6	7.1	7.1	7.1	7.3	7.1	7.1	7.0	7.5	8.2	8.2	8.6	8.4	8.4	8.5
Venezuela	0.7	0.8	0.8	0.7	0.5	0.3	0.1	0.3	0.3	0.0	0.1	0.4	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.0
					2.0			2.0	2.0											5.5

important advantages of considering patent enforcement in the assessment of IP systems: (i) divergence between book law and enforcement, (ii) volatility in patent enforcement over time including decreases in the enforceability of patents, (iii) the opportunities from disaggregating changes in the overall index using the three transaction cost sub-indices as well as (iv) the benefits of incorporating firm-level patent litigation information into PEI compared with PSS.

### 4.1. Divergence between book law and enforcement

Park (2008) provides the most widely used index for the strength of patent protection relying exclusively on patent book laws. We compare index values with PEI for the year 2010.<sup>6</sup> Fig. 2 shows the results and highlights the divergence between patent book laws and enforcement in

virtually all countries covered.7

The large difference in the scores between the two indices showcases PEI's explanatory value of measuring patent enforcement separately from measuring the availability of patent law in a country. The most striking differences emerge when comparing patent systems of many developing countries. Following the Park (2008) index, developing countries such as Argentina, Brazil, Mexico, Indonesia and South Africa strengthened their patent laws on the books after the signing the TRIPS agreement. However, TRIPS does not contain regulations that oblige countries to provide effective enforcement of patents. PEI reveals, accordingly, that the strength of enforcing patent laws remains weak in practice.

 $<sup>^{6}</sup>$  The latest updated data of the Park (2008) index are available at Professor Park's (2019) personal website.

<sup>&</sup>lt;sup>7</sup> To enable a meaningful comparison between the scores of the two indices, we transform the Park (2008) index scores from a scale of 0 to 5 to a scale of 0 to 10. As also mentioned in Papageorgiadis et al. (2014, p. 594), "Such transformation is not appropriate statistically but is done to show visually the differences in country scores across the two indices".

Index scores of property rights protection costs construct.

Country	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Argentina	2.2	2.0	2.6	2.4	1.2	1.0	1.2	1.5	1.7	1.7	1.7	1.8	2.0	2.0	2.3	2.3	2.2	2.2	2.6	3.0
Australia	8.8	8.9	8.6	8.7	8.8	8.9	8.9	8.8	8.8	8.7	8.8	8.8	8.7	8.8	8.5	8.0	8.0	8.1	8.1	7.9
Austria	7.6	7.7	7.9	8.0	7.8	7.8	8.3	8.5	8.5	8.1	8.1	7.9	7.8	7.6	6.6	6.6	6.9	7.3	7.4	7.4
Belgium	4.7	4.8	5.9	6.5	6.4	7.0	7.1	6.9	6.9	6.8	7.1	6.7	6.7	7.1	7.1	7.2	7.3	7.4	7.4	7.2
Brazil	3.5	3.7	3.5	3.4	3.5	3.3	3.4	2.8	2.4	2.6	2.9	3.0	2.9	3.1	3.6	3.6	3.5	3.1	3.4	3.2
Canada	9.3	9.3	9.3	9.0	9.0	8.4	8.5	8.2	8.4	8.6	8.8	8.7	8.9	8.8	8.5	8.2	8.2	8.3	8.3	8.3
Chile	6.2	6.3	6.6	6.6	6.6	6.7	6.8	6.4	6.4	6.3	6.2	6.2	6.8	6.9	6.8	6.7	6.8	6.5	6.1	6.2
China	3.0	2.6	2.4	2.7	3.4	2.9	3.0	2.7	2.9	3.1	3.2	3.2	3.1	3.2	3.4	3.5	3.2	3.4	3.6	3.9
Colombia	1.3	2.0	2.1	2.7	2.6	2.7	2.7	3.0	3.1	3.1	3.2	2.9	2.7	2.7	2.6	2.5	2.5	2.5	2.5	2.5
Czech Republic	4.4	4.1	3.9	3.4	3.3	3.5	3.9	3.9	4.1	4.5	4.6	4.2	4.0	3.8	4.1	4.1	4.4	5.1	5.2	5.2
Denmark	9.9	10.0	9.9	9.6	9.6	9.6	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.4	8.9	9.0	9.2	9.0	8.9	8.7
Estonia	-	-	-	5.3	5.2	5.4	5.9	5.9	6.4	6.2	6.3	6.3	6.3	6.2	6.2	6.5	6.7	6.8	6.8	6.9
Finland	9.6	9.8	10.0	9.8	9.6	9.7	9.4	9.4	9.5	9.4	9.0	9.0	9.1	9.3	9.0	9.0	9.0	9.1	9.0	8.8
France	6.3	6.5	6.3	6.6	5.7	6.3	6.7	7.1	7.0	7.0	6.8	6.5	6.5	6.7	6.8	6.9	6.6	6.8	6.7	6.8
Germany	8.1	8.3	8.0	7.8	7.5	7.8	8.3	8.3	8.2	8.0	8.1	8.2	8.1	8.2	8.0	7.9	7.9	8.0	8.0	7.9
Greece	4.3	4.3	4.5	4.0	3.9	4.1	4.1	3.8	4.1	4.3	4.2	3.2	3.0	2.8	2.8	3.3	3.6	4.0	3.7	4.1
Hong Kong	7.6	7.5	7.4	7.7	7.9	7.7	7.8	7.9	8.2	8.1	8.0	8.1	8.2	8.3	7.7	7.7	7.5	7.7	7.8	7.7
Hungary	4.8	5.1	4.9	5.1	4.4	4.5	4.4	4.5	4.7	4.8	4.5	4.5	4.0	4.0	4.6	4.6	4.6	4.1	3.8	3.6
Iceland	8.9	8.8	8.9	9.0	9.2	9.5	9.4	9.3	9.4	9.0	8.7	8.5	8.2	8.1	8.0	7.6	7.6	7.7	7.6	7.5
India	3.1	3.1	3.0	3.0	2.9	3.0	2.9	3.1	3.8	3.8	3.5	3.6	3.4	3.0	3.6	3.6	3.6	3.6	3.8	3.8
Indonesia	1.0	0.7	0.8	0.9	0.8	1.1	1.4	1.4	1.5	1.5	2.0	2.3	2.3	2.3	2.5	2.6	2.9	3.1	3.1	3.3
Ireland	8.3	7.7	7.4	7.6	7.1	7.3	7.5	7.5	7.6	7.5	7.8	8.0	8.0	7.6	7.2	7.4	7.6	7.7	7.5	7.6
Israel	7.2	7.0	6.9	7.7	7.3	7.2	6.3	6.3	6.3	6.3	6.1	6.3	6.4	6.2	6.2	6.3	6.2	6.4	6.7	6.5
Italy	4.1	4.1	4.0	5.0	4.7	4.7	4.1	4.2	4.1	4.4	4.0	3.4	3.2	3.4	3.6	3.6	3.5	3.7	4.0	4.4
Japan	6.0	6.2	6.5	7.0	6.7	6.5	6.8	7.0	7.5	7.3	7.1	7.5	7.7	7.9	7.3	7.4	7.7	7.6	7.3	7.4
Jordan	_	_	_	_	_	4.6	4.9	5.3	5.1	4.5	5.0	4.8	4.3	4.1	4.4	4.1	4.5	5.0	4.6	4.5
Korea (South)	3.6	3.1	3.5	3.7	4.1	3.9	4.2	4.6	4.6	5.0	5.3	4.9	4.8	4.8	5.1	4.7	4.6	4.8	4.6	4.7
Malaysia	5.0	4.4	4.0	4.1	4.4	4.8	4.9	5.1	5.0	5.0	4.8	4.0	4.1	4.1	4.6	4.7	5.0	4.7	4.6	4.4
Mexico	2.3	2.6	2.3	2.8	2.5	2.7	2.7	2.7	2.5	2.7	2.7	2.3	2.1	2.1	2.5	2.5	2.5	2.1	2.0	1.9
Netherlands	9.1	9.1	9.1	9.0	9.0	8.9	8.8	8.6	8.8	9.1	9.0	9.0	8.8	9.0	8.6	8.4	8.4	8.6	8.5	8.4
New Zealand	9.5	9.5	9.4	9.4	9.5	9.5	9.4	9.4	9.4	9.3	9.3	9.4	9.3	9.5	9.0	9.1	9.1	9.2	9.1	9.0
Norway	9.0	8.7	8.9	8.6	8.3	8.5	8.9	8.7	8.8	8.6	8.0	8.6	8.6	8.9	8.5	8.6	8.6	8.9	8.7	8.7
Philippines	2.5	2.8	2.2	2.3	1.9	1.6	1.8	1.5	1.8	1.8	1.7	1.6	1.4	1.7	2.5	2.7	3.0	2.8	2.8	2.7
Poland	4.2	3.8	3.6	3.8	3.2	3.0	2.6	2.6	2.9	3.4	3.8	4.3	4.7	4.9	5.1	5.3	5.3	5.4	5.3	4.8
Portugal	6.3	6.3	5.9	5.7	6.1	6.3	6.0	6.1	6.2	6.1	5.6	5.2	5.1	5.1	5.3	5.3	5.5	5.8	5.5	5.7
Romania	-	-	-	-	_	1.7	2.0	2.0	2.2	2.8	2.9	3.1	2.9	2.7	3.1	3.2	3.5	3.9	4.0	4.1
Russia	1.6	1.4	1.3	1.5	1.6	1.7	1.9	1.3	1.5	1.5	1.4	1.4	1.3	1.5	1.9	1.9	2.0	2.3	2.4	2.4
Singapore	8.7	8.6	8.8	8.9	8.8	8.9	8.8	8.9	8.8	8.8	8.9	8.8	8.9	8.7	8.4	8.3	8.2	8.2	8.1	8.1
Slovakia	_	_	_	3.1	2.8	2.8	3.3	3.5	3.9	4.0	4.1	3.6	3.1	2.8	3.3	3.2	3.5	3.8	3.8	3.7
Slovenia	-	-	-	4.7	5.6	5.2	5.1	5.2	5.7	5.8	5.8	5.8	5.5	4.9	5.1	4.7	4.7	5.1	5.1	5.1
South Africa	4.9	4.7	4.9	4.9	4.9	4.5	4.8	4.4	4.7	5.0	4.7	4.4	4.1	4.0	4.3	4.2	4.4	4.5	4.6	4.1
Spain	5.8	6.3	6.8	6.6	6.3	6.0	6.3	6.2	5.8	5.7	5.7	5.2	5.2	5.4	5.6	5.7	4.8	5.0	5.0	5.1
Sweden	9.2	9.2	9.2	9.0	8.9	9.1	9.0	8.5	8.9	9.1	9.3	9.2	9.2	9.3	8.8	8.8	8.5	8.9	8.9	8.5
Switzerland	9.0	9.0	8.7	8.6	8.3	8.6	9.0	9.0	9.0	9.0	9.1	9.0	8.8	8.9	8.7	8.5	8.6	8.7	8.7	8.7
Taiwan	47	5.0	4.8	5.2	49	5.2	5.2	5.3	5.2	5.2	5.3	5.2	5.4	5.8	5.8	5.7	5.5	5.7	5.6	5.8
Thailand	2.9	3.1	3.1	3.2	3.1	3.2	3.4	3.5	3.3	3.1	3.2	3.1	3.2	3.1	3.6	3.0	3.2	3.3	3.1	3.3
Turkey	3.0	2.9	3.3	3.0	2.4	2.5	2.6	2.9	3.4	3.7	4.0	3.7	3.5	3.3	4.0	4.0	3.4	3.1	3.1	2.9
USA	7.5	7.5	7.8	7.7	7.7	7.4	7.2	7.4	7.0	6.9	7.2	7.2	6.8	6.8	7.0	7.0	7.1	7.4	7.2	7.4
Ukraine	_	-	_	_	_	_	_	_	_	1.6	1.5	1.1	1.2	1.1	1.5	1.3	1.4	1.6	1.7	2.0
United Kingdom	8.8	8.6	8.8	8.4	8.6	8.6	8.5	8.4	8.5	8.3	7.6	7.7	7.8	7.9	7.6	7.8	7.9	8.2	8.2	8.3
Venezuela	1.3	1.5	1.4	14	0.9	0.5	0.7	07	0.6	0.4	0.3	0.4	0.4	0.4	0.2	0.3	0.2	0.0	0.0	0.1
· monuta	1.0	1.0			0.2	0.0	0.7	0.7	0.0		0.0				0.2	0.0	0.2	0.0	0.0	0.1

However, the divergence between patent book laws and enforcement is not limited to developing countries. A number of countries appear to provide strong patent systems in terms of the availability of patent law on the books. However, these countries score low in terms of the effectiveness of the enforcement of the law in practice. For example, developed countries such as Canada, France, Portugal, Italy, Spain, and the USA score divergently in the two indices, having higher scores in relation to the strength of patent law on the books but lower scores for the strength of patent enforcement. In some cases such as Singapore and Switzerland, the strength of patent law on the books is weaker compared to the enforcement of patent law in practice. Such differences are usually evident in countries that strategically opt out of the membership in some international, patent-related treaties or decide not to grant patent rights for specific types of technological inventions, usually to protect domestic business interests (Papageorgiadis & McDonald, 2019).

The divergence in the scores of the Park (2008) index compared to PEI is due to the different focus of the two indices and the emergence of

a two speed national patent systems in the years after the implementation of the TRIPS agreement. First, introducing patent laws in a patent system is the first action that policy makers take to reform the patent system of their country. Once a country incorporates a patent law in its patent system, it is unlikely that it will withdraw it. Many countries drastically adopted a number of new patent related legislations to comply with TRIPS, however they were not ready to enforce them (Papageorgiadis & McDonald, 2019). This created two speed patent systems where most WTO counties provide comprehensive coverage in terms of patent law however, some effectively enforce patent law whereas others offer ineffective and restricted enforcement of patent law in practice. For example, Brander et al. (2017, p. 915-916) highlight that: "...a widely used index of patent protection developed by Ginarte and Park (1997) suggests that "China had a dramatic improvement in patent protection between 1990 and 2005. However, the actual implementation of those laws and standards has been lacking...China continues to exhibit a high and growing level of IPR infringement activity". Using both the Park (2008) and new PSS index can

Index scores of monitoring costs construct.

Country	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Argentina	4.0	4.2	3.6	3.3	2.2	2.5	1.9	2.8	2.6	2.4	2.1	2.0	2.1	2.1	1.9	1.7	1.9	3.6	3.9	4.1
Australia	8.4	8.9	8.9	9.1	9.0	9.1	9.0	8.4	8.8	8.6	8.8	8.7	8.3	8.1	8.0	7.9	8.2	8.7	8.8	8.7
Austria	8.9	8.9	9.5	9.3	9.3	8.2	8.8	8.2	8.5	8.9	9.1	9.1	8.8	8.4	8.3	8.1	8.2	8.5	8.6	8.8
Belgium	7.8	8.3	8.9	8.0	8.3	7.8	8.0	7.3	8.1	8.3	7.9	7.7	7.5	7.6	7.7	7.7	7.8	8.7	9.0	8.8
Brazil	5.2	5.9	5.8	5.2	4.7	4.3	3.9	3.3	3.9	3.5	3.6	3.4	3.5	3.6	4.0	4.1	3.8	4.9	5.0	5.1
Canada	8.6	8.7	8.8	8.6	8.5	7.9	8.4	8.0	8.2	8.2	8.1	7.8	8.1	7.8	7.9	8.2	8.4	8.7	8.6	8.5
Chile	5.6	6.4	6.7	5.7	5.1	5.2	4.7	4.7	4.9	4.4	4.1	4.4	4.1	4.3	4.5	4.7	4.8	5.4	5.5	5.6
China	3.8	4.3	4.4	3.1	3.7	3.4	3.8	3.1	3.6	3.7	4.4	4.3	4.4	4.3	4.3	4.3	4.4	4.9	4.8	5.2
Colombia	3.3	3.9	3.8	3.5	4.1	4.0	3.9	3.8	4.5	4.0	3.8	3.3	3.4	3.6	3.7	3.7	3.6	5.1	5.1	4.9
Czech Republic	4.7	4.7	5.0	5.9	6.1	4.8	5.2	4.9	5.3	5.1	4.9	5.3	5.3	5.0	5.2	5.4	5.3	6.7	6.8	7.0
Denmark	8.3	8.8	8.5	9.4	9.1	9.3	9.4	8.8	9.5	9.5	9.3	9.1	8.6	9.0	8.2	7.8	8.1	8.6	8.6	8.7
Estonia	_	_	_	5.5	6.1	6.3	6.4	5.7	6.3	6.4	6.6	6.2	6.3	6.5	6.5	6.5	6.8	7.8	7.8	7.5
Finland	8.6	8.6	9.4	9.7	9.5	9.3	9.1	8.8	9.6	9.2	9.1	9.1	9.3	9.3	9.3	9.2	9.3	9.6	9.7	9.9
France	8.7	8.7	9.0	9.5	8.0	8.3	8.1	8.1	8.3	8.2	8.6	8.2	8.6	8.3	8.2	8.4	8.4	8.7	8.8	8.6
Germany	8.9	9.4	9.4	9.5	8.9	9.2	9.2	9.4	9.7	9.6	8.9	8.4	8.6	8.5	8.5	8.5	8.2	8.9	8.7	8.7
Greece	4.5	5.1	5.1	4.9	4.7	5.2	5.5	4.9	5.4	5.0	5.0	4.7	4.9	4.4	4.5	4.4	4.6	5.3	5.2	5.2
Hong Kong	6.1	5.6	6.1	6.4	8.3	7.1	7.3	6.7	7.5	7.4	7.5	7.4	7.6	7.9	8.1	8.1	8.2	8.7	8.7	8.5
Hungary	5.2	5.9	6.1	5.6	5.9	5.8	5.8	5.5	6.2	5.9	5.5	5.1	5.5	5.6	5.5	5.3	5.0	5.1	5.1	5.4
Iceland	-	7.3	7.2	7.9	7.8	8.2	8.5	8.2	8.7	8.3	8.4	7.7	7.3	7.4	7.6	6.9	6.8	8.1	8.0	8.1
India	3.3	3.7	3.9	3.0	3.5	3.6	3.7	4.5	5.3	4.7	4.2	4.2	4.1	4.1	4.2	4.3	4.2	5.4	5.5	5.2
Indonesia	3.2	2.8	2.9	2.4	1.4	3.0	3.7	2.6	3.3	2.9	2.6	3.5	3.9	3.5	3.8	4.2	4.7	4.6	4.5	5.0
Ireland	7.7	7.3	7.3	7.6	7.1	6.8	7.4	8.0	7.6	7.9	8.0	8.1	8.1	8.4	8.1	8.1	8.4	8.9	8.9	8.8
Israel	7.1	6.8	6.8	6.8	7.2	7.9	6.9	7.0	7.5	7.1	6.1	5.2	6.0	6.4	6.9	6.7	6.8	8.4	8.5	8.8
Italy	6.3	6.6	7.0	7.6	6.2	5.9	4.7	5.3	5.3	5.4	5.6	4.7	4.6	4.7	4.8	4.7	4.7	5.7	5.8	5.9
Japan	7.3	8.1	7.8	7.9	6.2	6.8	7.5	7.5	8.5	8.1	8.2	8.0	7.7	8.0	7.9	8.6	9.0	8.6	8.6	8.6
Jordan	-	-	-	-	_	6.4	6.3	5.9	5.4	5.8	6.1	6.2	5.5	5.3	5.8	5.9	6.0	6.6	6.4	6.3
Korea (South)	4.9	4.8	5.1	5.1	5.8	5.7	5.3	5.8	5.8	7.0	6.4	5.6	5.4	5.5	5.8	5.2	4.7	6.1	5.9	5.8
Malaysia	6.1	5.4	5.2	3.9	5.6	6.3	6.2	6.4	6.7	6.8	6.2	5.8	6.3	6.6	6.8	6.6	7.2	7.3	7.2	7.2
Mexico	5.1	5.7	5.8	4.6	3.4	4.2	3.4	3.4	4.1	3.7	3.3	3.4	3.2	3.7	4.1	4.3	4.0	5.1	5.2	5.0
Netherlands	9.3	8.9	9.2	9.7	9.1	8.7	8.9	8.8	9.4	9.0	8.7	8.7	8.5	8.6	8.9	8.6	8.5	9.3	9.4	9.4
New Zealand	8.5	7.7	8.4	8.0	7.9	8.4	8.6	8.5	8.6	8.8	8.6	8.8	8.4	8.6	8.9	8.7	8.8	9.1	9.1	9.2
Norway	8.3	7.9	7.9	7.8	7.5	7.5	8.7	7.7	8.4	7.8	8.3	8.1	8.2	8.3	8.0	8.3	8.4	8.9	9.0	8.8
Philippines	3.7	4.8	4.7	3.1	2.4	2.7	2.4	2.5	2.9	3.0	3.2	2.7	2.7	2.7	3.2	3.9	4.1	4.6	4.6	4.9
Poland	4.6	4.3	4.5	4.8	3.9	3.9	2.9	3.9	3.7	3.8	4.0	4.1	4.5	4.7	4.5	5.0	4.7	5.5	5.7	5.1
Portugal	5.7	6.3	6.8	6.7	6.2	6.3	6.1	6.7	6.8	6.7	6.6	6.4	5.8	5.8	6.0	6.2	6.1	6.6	6.7	6.9
Romania	-	-	-	-	_	2.7	3.2	2.8	2.9	3.1	3.9	3.5	3.4	3.4	2.8	3.0	3.8	5.0	5.0	5.6
Russia	2.3	1.6	2.2	1.2	1.9	1.6	2.4	1.6	1.7	2.1	2.3	2.3	2.1	2.0	2.3	2.7	3.2	3.4	3.6	4.0
Singapore	7.9	8.2	8.4	8.2	8.3	8.6	8.4	8.9	8.9	9.3	9.4	9.2	9.1	9.1	9.1	9.1	9.2	9.4	9.4	9.2
Slovakia	_	_	_	4.7	4.6	4.7	4.9	4.7	4.9	4.8	4.7	4.6	4.8	4.7	4.8	4.8	4.9	5.6	5.6	5.8
Slovenia	-	-	-	5.1	6.2	5.9	5.8	5.4	5.6	5.7	5.6	5.8	5.5	5.4	5.6	5.3	5.2	6.3	6.4	6.3
South Africa	6.2	6.2	6.6	6.3	7.0	6.5	6.9	6.7	7.0	7.2	7.3	7.4	7.0	7.0	7.6	7.8	7.4	7.9	8.0	6.9
Spain	7.0	6.9	7.5	7.1	6.2	6.3	6.1	5.7	6.4	6.4	6.2	5.7	5.7	5.5	5.2	5.2	4.7	6.2	6.1	6.1
Sweden	8.3	9.0	7.8	8.7	9.0	9.1	9.4	8.2	9.0	8.7	8.8	9.0	9.3	9.0	8.5	8.4	8.3	9.1	9.2	8.8
Switzerland	9.3	9.4	9.4	9.8	9.2	9.0	9.1	9.2	9.7	9.6	9.5	9.2	9.2	9.3	9.2	9.2	9.2	9.9	9.9	10.0
Taiwan	7.0	7.1	6.8	6.2	6.1	6.7	6.6	6.6	6.4	6.6	6.7	6.9	6.9	7.1	7.4	7.4	7.1	7.3	7.3	7.3
Thailand	4.2	4.4	4.7	4.1	4.6	4.8	4.6	4.6	4.8	4.2	4.1	3.4	3.1	3.1	3.1	3.1	3.1	3.3	3.6	3.9
Turkey	4.2	4.7	5.4	3.5	2.9	3.0	2.7	3.2	3.4	3.5	3.2	2.8	2.6	2.9	3.6	4.1	4.1	4.0	4.3	4.3
USA	9.2	9.4	9.6	10.0	9.8	9.4	9.4	9.6	8.6	8.0	8.5	8.0	7.8	7.7	6.3	8.0	8.3	8.9	9.0	8.8
Ukraine	_	_	_	_	_	_	_	_	_	2.1	2.0	2.1	1.9	1.9	1.8	1.7	2.1	2.6	2.8	2.8
United Kingdom	8.7	9.1	9.6	9.2	9.5	8.9	8.7	8.5	8.8	8.6	7.7	7.7	8.2	8.5	8.8	8.6	8.9	9.2	9.2	9.4
Venezuela	2.2	3.2	2.6	3.2	1.8	1.9	1.7	1.5	1.2	0.9	0.8	0.8	0.4	0.4	0.1	0.1	0.0	0.5	0.6	0.6

enable researchers to identify the divergence between the availability of patent law and the enforcement of patent law in practice, and capture the overall strength of a patent system in a more precise and accurate way.

In sum, the divergence in strengths of patent book laws and patent enforcement for many countries suggests that research intended to capture the strengths of patent systems in a comprehensive, unbiased way should complement indices relying on book laws (such as Park, 2008) with PEI for measuring otherwise unobserved, non-random differences in patent enforcement.

### 4.2. Volatility and decline in patent enforcement over time

PEI scores reveal that many of the 51 countries considered in the study have experienced dynamic changes over the twenty-year time period. However, such changes are not captured in other patent and IP indices to date. For example, the latest update of the Park (2008) index for the year 2010 suggests that the UK patent system is consistently

stable with a score of 4.54 out of 5 over the last 15 years. In contrast, the UK Intellectual Property Office's (IPO) has drastically increased its focus on reforming and improving its patent system since 2006. Reforms of the UK's patent system were initiated with the first holistic review of the overall IP system in 2006, known as Gowers Review, and the gradual implementation of the UK IP strategy over the years 2010-2017 (Gowers, 2006; IPO, 2015). Important aspects of the enforcement related reforms in the UK patent system between 2010-2013 include changes in the Intellectual Property Enterprise Court (IPEC) that introduces "a cap on recoverable costs and damages and reduced the length as well as complexity of court actions" (IPO, 2017, p. 30). The aim of this reform was to reduce the transaction costs that firms face when interacting with the judicial enforcement component of the patent system. Consistent with PEI, a subsequent review of the reform revealed that this reform was successful and responsible for a large increase in the number of patent litigation cases at IPEC, particularly from small and medium sized enterprises (Helmers, Lefouili, & McDonagh, 2015; IPO, 2017). Such changes in the strengthening of the

Scores of the overall Patent Enforcement Index.

Country	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Argentina	3.9	3.9	3.8	3.6	2.6	2.7	2.5	2.9	3.0	2.8	2.8	2.7	2.9	2.9	2.9	2.9	2.8	3.4	3.9	4.0
Australia	8.6	8.8	8.7	8.8	8.8	8.9	8.9	8.4	8.6	8.6	8.7	8.7	8.4	8.5	8.3	8.0	8.3	8.3	8.4	8.2
Austria	7.8	8.0	8.4	8.5	8.4	7.9	8.4	8.3	8.4	8.4	8.4	8.1	8.0	7.8	7.5	7.3	7.3	7.3	7.4	7.6
Belgium	6.5	6.6	7.2	7.1	7.2	7.2	7.2	6.9	7.2	7.3	7.2	6.9	6.9	7.1	7.2	7.2	7.2	7.7	7.9	7.7
Brazil	4.2	4.3	4.4	4.1	4.0	3.7	3.5	3.0	3.1	3.0	3.1	3.2	3.0	3.3	3.5	3.5	3.3	3.5	3.6	3.6
Canada	8.8	8.9	8.9	8.7	8.7	8.1	8.5	8.2	8.4	8.4	8.5	8.3	8.4	8.5	8.4	8.4	8.4	8.7	8.5	8.4
Chile	5.8	6.2	6.4	6.0	5.9	6.0	5.9	5.8	5.8	5.4	5.3	5.3	5.4	5.8	6.1	5.8	5.8	5.8	5.6	5.7
China	4.0	3.9	4.0	3.8	4.4	4.1	4.0	3.8	4.2	4.3	4.6	4.3	4.4	4.5	3.9	3.9	3.9	4.1	4.2	4.6
Colombia	2.4	2.8	2.8	3.0	3.2	3.4	3.4	3.2	3.7	3.4	3.5	2.9	2.9	3.2	3.0	3.0	2.9	3.4	3.4	3.3
Czech Republic	4.8	4.5	4.6	4.7	4.8	4.4	4.6	4.6	4.9	4.8	4.9	4.8	4.9	4.8	4.8	4.8	4.9	5.7	5.7	5.7
Denmark	9.1	9.3	9.1	9.2	9.3	9.2	9.5	8.9	9.5	9.4	9.2	9.1	8.7	9.0	8.6	8.6	8.6	8.6	8.8	8.8
Estonia	_	_	_	5.4	5.4	5.7	5.9	5.6	6.1	6.0	6.1	5.7	5.9	5.9	6.1	6.2	6.3	6.6	6.6	6.6
Finland	9.2	9.5	9.7	9.7	9.6	9.6	9.3	9.1	9.6	9.0	8.8	9.1	9.2	9.3	9.2	9.2	9.2	9.1	9.1	9.1
France	7.5	7.5	7.6	7.3	6.4	6.8	6.9	7.1	7.1	7.0	7.0	6.9	6.9	7.0	6.9	7.0	6.8	6.9	6.9	7.0
Germany	8.3	8.5	8.5	8.5	8.0	8.1	8.3	8.4	8.5	8.5	8.3	8.2	8.2	8.3	8.4	8.3	8.2	8.3	8.3	8.3
Greece	4.4	4.7	6.0	4.6	4.3	4.5	4.6	4.3	4.6	4.6	4.5	4.0	4.0	3.7	3.7	4.1	4.1	4.5	4.3	4.4
Hong Kong	7.1	6.8	6.9	7.0	7.6	7.3	7.3	7.1	7.7	7.6	7.4	7.3	7.2	7.6	7.8	7.6	7.4	7.8	8.0	7.8
Hungary	5.8	6.2	6.2	5.9	5.9	5.9	5.2	5.0	5.3	5.3	5.0	4.7	4.6	4.8	4.9	4.8	4.7	4.5	4.4	4.5
Iceland	_	8.2	8.4	8.6	8.7	9.0	9.0	8.8	9.1	8.9	8.9	8.5	7.7	7.7	7.8	7.4	7.4	7.9	7.9	7.9
India	3.9	3.9	4.1	3.7	3.8	3.9	4.0	4.3	5.0	4.6	4.5	4.5	4.4	4.3	4.5	4.5	4.5	4.9	5.2	5.0
Indonesia	2.5	2.6	2.8	2.2	1.9	2.2	2.5	2.3	2.5	2.4	2.7	2.9	3.1	3.0	3.3	3.5	3.7	3.6	3.9	4.0
Ireland	8.3	7.8	7.9	8.0	7.5	7.2	7.5	7.7	7.8	7.8	7.9	8.0	7.9	8.0	7.9	7.9	8.2	8.4	8.3	8.3
Israel	7.4	7.3	7.2	7.5	7.4	7.4	6.8	6.9	7.1	6.9	6.5	6.2	6.6	6.7	6.8	6.8	6.7	7.4	7.5	7.5
Italy	5.2	5.2	5.3	5.8	5.0	5.1	44	4.6	4.5	4.6	4.5	41	4.0	4 1	4.2	4.0	4.0	44	47	47
Janan	6.8	7.2	7.3	74	6.8	7.0	7.3	74	8.0	7.8	77	77	79	79	7.8	81	8.4	82	82	82
Jordan	-	_	-	_	_	49	5.0	49	47	47	49	47	42	4.2	4.6	4.5	49	5.2	47	4.8
Korea (South)	4.5	4.3	4.7	4.9	5.2	5.1	5.1	5.5	5.5	6.0	5.5	5.2	5.2	5.4	5.6	5.5	4.9	5.4	5.2	5.2
Malaysia	5.8	5.2	5.1	4.5	5.4	5.9	5.8	5.6	6.0	6.0	5.6	5.1	5.6	5.7	61	5.9	6.3	6.2	5.9	5.9
Mexico	4 1	4 4	4 4	4 1	3.5	3.9	3.5	37	3.8	3.6	3.5	3.4	3.1	3.5	3.9	4.0	3.6	3.6	37	3.6
Netherlands	9.1	89	9.2	9.0	8.9	8.5	8.5	8.4	87	87	8.6	8.5	8.3	87	8.8	8.6	8.4	8.8	8.9	8.9
New Zealand	9.0	8.5	87	8.4	8.5	8.5	8.4	8.5	8.5	8.5	8.5	8.5	8.3	87	87	8.6	8.8	8.8	8.9	8.9
Norway	87	8.2	8.3	7.8	79	8.0	8.5	8.0	8.6	8.2	8.0	8.2	81	8.4	81	8.3	8.4	8.6	8.6	87
Philippines	3.8	41	3.9	33	29	3.0	2.9	2.8	3.0	3.1	3.0	2.8	2.8	2.9	35	3.8	4.0	4.0	3.9	4 1
Poland	4.3	4.2	4 4	4.3	37	3.7	3.2	3.5	3.5	3.7	4.0	4.2	4 4	47	47	5.2	4.9	5.3	5.3	4.9
Portugal	5.6	5.8	5.8	5.7	5.5	5.7	5.5	5.8	5.8	5.9	5.7	5.6	53	5.4	5.6	5.5	5.5	5.9	5.7	5.8
Romania	_	-	_	-	_	17	19	17	2.0	24	24	23	24	24	2.2	2.5	2.5	3.4	3.4	35
Russia	17	12	14	12	14	13	17	11	15	15	15	15	14	15	1.6	1.9	23	24	2.6	27
Singapore	87	89	91	8.8	9.0	8.9	87	91	9.0	93	9.2	8.9	9.0	8.9	9.0	8.8	87	9.0	9.0	89
Slovakia	_	-	_	4.0	3.9	4.0	44	4.4	4.6	4.6	4.6	4 4	4.2	4.0	4.2	41	43	4.6	4.8	47
Slovenia	_	_	_	47	5.4	53	5.1	5.0	53	5.4	5.4	5.6	5.1	4.9	5.0	47	47	5.2	5.6	57
South Africa	52	48	5.0	4.9	5.2	49	5.1	4.8	5.0	5.0	49	49	47	4.6	5.0	5.1	5.0	49	5.1	4.6
Snain	63	6.6	71	7.2	6.8	67	63	5.8	5.8	5.0	5.6	51	5.1	53	53	5.1	47	5.2	53	53
Sweden	87	8.8	87	89	9.0	89	9.0	83	87	85	8.8	8.8	8.8	91	87	87	85	8.8	8.8	8.6
Switzerland	9.1	9.2	9.1	91	8.9	8.9	8.8	9.0	9.1	93	9.1	9.0	8.9	91	9.1	89	9.1	9.2	93	93
Taiwan	5.9	6.1	5.8	5.7	57	5.9	6.0	6.0	5.0	6.0	6.1	6.0	6.4	6.5	6.7	6.6	6.4	6.5	6.5	6.6
Thailand	35	3.7	3.7	3.6	3.8	41	4.0	4.0	4.0	35	3.6	33	33	33	3.6	33	3.2	33	35	37
Turkey	3.5	3.7	41	3.0	27	7.1 27	2.0	3.1	33	3.5	3.5	3.3	3.5	3.5	3.8	41	3.2	3.5	3.5	3.7
USA	84	85	8.8	87	8.8	85	85	8.4	81	7.8	8.0	77	7.6	7.8	74	7.9	81	8.2	83	83
Ukraine	-	-	-		-	-	-	-		14	1.2	1.2	,.0	,.0	13	1.0	14	1.6	17	1.8
United Kingdom	87	86	89	84	85	84	81	80	81	81	7.5	7.5	7.6	8.0	8.2	8.2	85	8.6	8.6	87
Venezuela	14	1.8	1.6	1.9	11	0.4	0.1	0.0	0.1	0.1	0.4	0.5	03	0.0	0.2	0.2	0.5	0.0	0.0	0.7
* CHCZUCIU	1.7	1.0	1.0	1.0	1.1	0.7	0.7	0.0	0.7	0.7	0.7	0.0	0.5	0.0	0.2	0.2	0.1	0.2	0.2	0.2



Fig. 1. PEI scores by component for the year 2017.



Fig. 2. PEI scores compared with Park (2008) for the year 2010.

UK patent system are effectively captured by PEI, which shows a notable strengthening trajectory for the UK patent system from the high score of 7.6 in the year 2010 to an even higher 8.7 in the year 2017. These notable changes in the UK's patent system have not been noticed in extant other patent and IP indices available in the literature.

Similarly, countries that offer relatively weak levels of patent strength also experienced notable score increases during this time period, such as Romania from a score of 1.7 in 2003 to 3.5 in 2017. Other IP indices fail to capture such volatility. Romania has, for example, the exact same high score of 4 out of 5 for the years 2005 and 2010 in the updated index by Park (2008). However, Romania's upward trajectory captured by PEI is confirmed by other sources. As the US Trade Representative (USTR, 2015, p. 64) suggests, "The Romanian National Customs Authority also has done impressive work, more than doubling the number of counterfeit goods it seized in 2014 from the previous year".

PEI also reveals that many countries experienced negative dynamics in the strength of their patent enforcement. The identification of negative dynamics by PEI contrasts with the index scores of other patent and IP indices. For example, the index by Park (2008) reported that only one country out of 110 experienced a decline in its index scores (Slovak Republic, 1995: 2.96, 2000: 2.76). The latest update of the Park (2008) index continues to mainly report stable or strengthening patent systems. Out of 122 countries, only four countries experienced a small decline in their scores between 2005–2010 (Bangladesh from 1.70 to 1.58; Bolivia from 2.98 to 2.85; Cyprus from 3.48 to 3.14; Turkey from 4.01 to 3.88).

In contrast, the strength of patent enforcement of many of the countries included in PEI weakened during the time period after TRIPS. In particular, PEI reveals that, for example, Mexico and Venezuela experienced notable declines in in the strength of their patent enforcement, with Mexico's scores falling from 4.4 in 2000 to 3.6 in 2017 and Venezuela's declining from the already low score of 1.6 in the year 2000 to a score of 0.2 in the year 2017. Hungary experienced a reduction of 1.7 points for the same time period. The Spanish patent system experienced the largest decline of an advanced economy in PEI over this time period, a reduction of 1.7. While the scores for Spain could be partly attributed to recession-related economic difficulties that can lead to fewer police and customs enforcement actions as well as delays in in the administration of patent rights, problems leading to the weakening of patent enforcement can be deeper. For example, there are questions regarding judicial enforcement in Spain and its equivalence to other countries.

Comparing the volatility of PEI's three transaction costs sub-indices can also reveal cases of sudden dynamic increases or drops in the scores in only one of the three sub-indices of a country. For example, the monitoring costs sub-index score of the US increased from 6.3 in 2012 to 8.0 in 2013, while the other two sub-indices remained relatively stable. The establishment of the Patent Trial and Appeal Board (PTAB) in 2012 allowed patent owners to reduce their monitoring costs by contesting the validity of a troll's patent at PTAB, instead of engaging in patent litigation at court (Intellectual Asset Magazine, 2018a; MIP, 2015). Patent owners used the PTAB enforcement option extensively and drastically reduced the number of patent troll litigations in the country (Intellectual Asset Magazine, 2018b; MIP, 2018). Similarly, sudden drops are often times related to government budgets for IP related law enforcement such as courts, police or customs. If these agencies are underfunded, it becomes harder for patent owners to identify and enforce their rights against infringements. During the economic crisis in Argentina in the time period 2001-2002, the property rights protection and monitoring sub-indices suddenly dropped from 2.4 to 1.2 for the former and from 3.3 to 2.2 for the latter. Servicing costs did not experience an equally drastic fall (from 5.2 to 4.5) in the same time period.

### 4.3. Disaggregation of the origin of changes in PEI

The reporting of the disaggregated annual scores of each of the three transaction cost sub-indices (Tables 3-5) in addition to the overall PEI index (Table 6), enables us to pinpoint areas in patent enforcement in each country facing high transaction costs. Following the example of the Spanish patent system, the disaggregated data allow us to identify that the servicing costs index score of Spain fell from 8.0 in 2001 to 4.8 in the year 2017. In contrast, the servicing cost scores of the UK patent system are relatively low over the twenty-year time period. However, the strengthening of patent enforcement in the UK over the last years is mainly driven by improvements in monitoring costs (from 7.7 in 2008 to 9.2 in 2017). Other countries score very low in one index and higher in the others. For example, Romania scores very low in the servicing costs index (from 0.5 in 2003 to 0.8 in 2017) whereas its scores in the property rights protection costs (from 1.7 in 2003 to 4.1 in 2017) and monitoring costs (from 2.7 in 2003 to 5.6 in 2017) indices are much stronger.

The scores of the three disaggregated indices reveal important differences about specific aspects of patent enforcement. We zoom in and evaluate the similarities in the scores of the three disaggregate indices further, by carrying out a Cronbach's a analysis of the disaggregate index scores by country. We report the results in Table 7 and plot the Cronbach's a scores with the average overall index scores of PEI by country over the 20 year period in Fig. 3. The results and a scatterplot confirm important differences in the scores of the three indices by country, demonstrating the significance of making available the disaggregate indices. We find that, in the majority of the cases most of the countries that achieve high Cronbach's alpha values (above 0.70) have either a very low or low average score of below 5 in PEI. Importantly, many of the countries that have higher than average scores in the overall PEI index, achieve lower Cronbach's a scores of the three disaggregate indices. Therefore, there is a divergence in servicing, protection and monitoring enforcement aspects for many of the countries that score high in PEI. This suggests that the strength of patent enforcement of countries develops unevenly with some aspects evolving more rapidly than others. In this sense, the sub-indices of PEI provide new opportunities to study the emergence of strong patent enforcement

Table	7
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Cronbach's alpha scores of the three transactions costs sub-indices per country.

Country	Cronbach's alpha	Country	Cronbach's alpha
Argentina	0.78	Korea (South)	0.63
Australia	0.71	Malaysia	0.66
Austria	0.70	Mexico	0.34
Belgium	0.26	Netherlands	0.43
Brazil	0.65	New Zealand	0.47
Canada	0.43	Norway	0.63
Chile	0.44	Philippines	0.77
China	0.71	Poland	0.84
Colombia	0.35	Portugal	0.66
Czech Republic	0.53	Romania	0.75
Denmark	0.63	Russia	0.87
Estonia	0.66	Singapore	0.52
Finland	0.65	Slovakia	0.70
France	0.45	Slovenia	0.71
Germany	0.63	South Africa	0.74
Greece	0.56	Spain	0.79
Hong Kong	0.36	Sweden	0.46
Hungary	0.58	Switzerland	0.44
Iceland	0.85	Taiwan	0.87
India	0.83	Thailand	0.29
Indonesia	0.68	Turkey	0.51
Ireland	0.30	USA	0.52
Israel	0.40	Ukraine	0.83
Italy	0.78	United Kingdom	0.71
Japan	0.82	Venezuela	0.82
Jordan	0.56		



Fig. 3. Comparison of PEI average scores and Cronbach's alpha scores of the three transaction cost constructs.

systems by pinpointing which aspects lead changes and which ones lag behind.

Overall, the availability of such disaggregated data is unique in the patent and IP index literature and can enable future researchers to use the aggregate or disaggregated data of PEI, depending on the specific theoretical focus of their research. For example, researchers aiming to measure specific enforcement related aspects of patent systems, such as monitoring costs, may use a more refined proxy compared to an aggregate index. Similarly, policy makers can target reforms to improve the performance of specific aspects of their country's patent system, and patent and IP practitioners can use the disaggregated data to inform their decision making for the expected transaction costs from specific elements of a patent system.

### 4.4. PEI compared to PSS

Comparing PEI and PSS index scores reveals the advantages of relying on firm-level patent litigation data as part of PEI. One would generally expect that an increase in the information content of an index makes it increasingly sensitive and timely for capturing changes based on private information emerging from condensing individual experiences and knowledge of a multitude of patent lawyers and managers through their litigation decisions compared with country-level data entering PSS. The data bears this out.

Overall, we observe that while the PEI and PSS scores are consistent with correlation coefficients ranging between 0.1 and 0.9 across countries with an average correlation of 0.63, the index scores of PEI are more sensitive, capturing the dynamics and trends of patent enforcement earlier compared to PSS. India provides a fitting example. Fig. 4 depicts the PEI and PSS index scores of India for the years 1998-2011 rescaled to 100 with 1998 as base year for comparability. PSS would suggest that the patent system in India has hardly changed in the period 2001-2004. In comparison, PEI is able to pick up an increasing strengthening of patent enforcement during that period. In fact, 2001-2005 is the period in which India started implementing TRIPS requirements related to patents. As part of India's aim to comply with the requirements of TRIPS, the country introduced the "Patents Amendment Act, 2002" and "Patent Rules, 2003". The 2002 act aimed to introduce "flexibility and reduce processing time for patent applications and to simplify and rationalize the procedures for granting of patents" (Intellectual Property Owners Association, 2007, p. 5). Such changes can clarify and improve the ability of patent owners to litigate and enforce their patents in practice (MIP, 2014). This created an anticipatory effect for patent owning firms that started engaging with the patent enforcement system of the country and prepared for the ability to use the new rules to improve their potential to succeed in enforcing their rights. While the PEI index is sensitive and captures this increasing trend of utilizing the TRIPS changes for the enforcement of patents, PSS



Fig. 4. Comparison of the PEI and PSS index scores of India for the years 1998-2011.

reacts only with significant delay in 2005. Both indices move consistently after 2005, the year in which India passed the "Patents (Amendment) Act, 2005" (Indian Ministry of Law & Justice, 2005).

Similar to the case of India, we find that the scores in PEI capture key trends much earlier compared to the PSS index for a number of other countries. For example, the UK Intellectual Property Office identified a number of underperforming areas in its patent system when undertaking its first holistic assessment in 2006 and gradually started implementing changes over the years 2010–2017. Fig. 5 depicts that the PEI scores start capturing the decline identified in the Gowers (2006) review during the years 2002-2005 already, a period during which the PSS scores are largely stable and converge afterwards. Other examples of the PEI scores capturing eventual PSS trends much earlier include Brazil (Fig. 6 depicts a PEI decline starting in 2001 that PSS only picks up in 2005), Spain (Fig. 7 shows PEI capturing the beginning of declines already in 2002 while PSS suggests stability until 2005), the Netherlands (Fig. 8 illustrates how PEI identifies declines starting in the years 2001 and 2008 to which PSS converges only with multiyear delays) or Chile (see Fig. 9 for the drop in PEI starting in 2001 that PSS starts converging to in 2005). It is noteworthy that the advantages of PEI for covering changes in patent enforcement in a timely fashion compared with PSS are not limited to a particular group of countries or region. Overall, the firm-level litigation data included in PEI identifies emerging trends significantly earlier than PSS for many countries. Accordingly, PEI delivers a much more timely assessment of patent



Fig. 5. Comparison of the PEI and PSS index scores of the United Kingdom for the years 1998-2011.



Fig. 6. Comparison of the PEI and PSS index scores of Brazil for the years 1998-2011.



Fig. 7. Comparison of the PEI and PSS index scores of Spain for the years 1998-2011.



Fig. 8. Comparison of the PEI and PSS index scores of the Netherlands for the years 1998-2011.

enforcement in a country than PSS could. Besides, it makes the analysis of trends and trajectories more meaningful.

Finally, PEI provides additional insights into patent enforcement compared with PSS even for countries with highly developed patent



Fig. 9. Comparison of the PEI and PSS index scores of Chile for the years 1998-2011.



Fig. 10. Comparison of the PEI and PSS index scores of Switzerland for the years 1998-2011.



Fig. 11. Comparison of the PEI and PSS index scores of Singapore for the years 1998-2011.

systems like Switzerland (see Fig. 10) or Singapore (see Fig. 11). While PSS would suggest that patent enforcement in Switzerland is virtually unchanged between 2004 and 2009, PEI reveals dynamic changes around the PSS multi-year average. Similarly, PSS is largely stable for

Singapore while PEI reveals a much wider variability in patent enforcement.

Taken together, the shared transaction cost framework for both PEI and PSS becomes apparent in the consistency between both indices. Then again, PEI benefits substantially from the additional information content that firm-level patent litigation data can provide. Apparently, this data contains important information based on the decisions of patent lawyers and managers that increases the sensitivity of PEI to country conditions. As a result, PEI captures changes to patent enforcement in a country much more comprehensively and in a much more timely fashion.

# 5. Conclusions

### 5.1. Implications for research

We conduct this study to provide researchers with a comprehensive, longitudinal index capturing differences in patent enforcement across countries that does not rely on the simplifying assumption that all IP laws on the books are seamlessly enforceable. For this purpose, we rely on the transaction cost framework of Papageorgiadis et al. (2014) and partly reconceptualise their PSS index to arrive at a new Patent Enforcement Index. PEI has two major advantages. First, we incorporate newly available firm-level patent litigation data across countries which allows us to capture three additional enforcement related aspects of national patent systems that capture the effect of patent litigation activities in a country. We conduct an extensive validation exercise involving 52 IP experts for reliably linking firm decisions on litigation across countries to differences in patent enforcement across countries. Following this validation process, we calculate the PEI index and provide annual index scores for the years 1998-2017 and 51 countries. Second, we provide the annual index scores for each of the three transaction costs constructs (servicing, property rights protection, monitoring) that comprise the overall PEI index.

PEI has two important implications for future research in international business in the area of international patent systems. First, we highlight a potential source of bias in international business research originating from overly strong assumptions on the overlap between IP book laws and enforcement. Instead, we find that the strength of patent enforcement is dynamic in national patent systems over time and PEI is particularly well positioned to capture changes in patent enforcement early by incorporating patent litigation decisions of patent lawyers and managers. We find that patent enforcement in many national patent systems has weakened over time, increasing the transaction costs for patent owning firms. While existing indices (such as Park, 2008) at least implicitly assume that the strength of patent systems is increasing linearly or remains constant over time, the weakening of patent systems is not conceptually and empirically considered. Hence, PEI can provide researchers in international business with a measurement of patent enforceability that can complement book law measures and avoid biases.

The opportunity to measure patent enforcement across 51 countries is salient for several core research topics in international business. Uncertainty emerging from a lack of patent enforcement is central to internationalization strategy and the management of MNCs. For example, such uncertainties affect the location choices of FDI and particularly of R&D activities across countries. Within this line of research, especially transaction costs economics models of internationalization rely explicitly on various types of uncertainty for explaining firm decisions and can benefit from precise measurements of the patent enforcement uncertainties. Similarly, the absence of appropriate measurements for informal institutions including patent enforcement limits theory on their origins and effects (Peng et al., 2017a).

Second, we decompose PEI into individual scores of each of the subindices. These sub-indices capture individual IP aspects, e.g. monitoring costs, which enables dedicated theory testing on individual aspects of IP systems across countries. The availability of PEI therefore enables research to go beyond the simplistic distinction between strong/weak patent systems.

### 5.2. Implications for managers and policymakers

Apart from its relevance for scientific research, the PEI index holds significant potential for the practice of IP management and policymaking. The potential for patent enforcement is one of the key strategic country-level factors that patent practitioners consider when deciding on the appropriate countries in which they will register and maintain their patent portfolios. Patent practitioners' decision making requires planning for the long-term given that patents can last up to 20 years and patent activities and enforcement take into account the length of the rights as well as supply chains and activities of competitor firms. Therefore they consider volatility in the strength of patent enforcement as an indicator of the longer term trajectory of patent enforcement strength. Patent practitioners can use the data of the PEI index to anticipate or confirm their expectations regarding the extent of transaction costs that they will experience when attempting to enforce their rights in a country. A firm may decide to discontinue its patenting activities of e.g. non-core patents in countries with weak or declining patent systems saving on the lifetime cost of each patent registration.

Policy makers can use PEI to benchmark the performance and trajectory of their country's patent system compared to the strength of the patent systems of other countries. They can then identify specific actions on how to strengthen components of their patent system and decrease the associated transactions costs that firms face when enforcing their rights in the country. For example, the Australian Government's productivity commission (2016) undertook a review of the effectiveness of their IP system in 2016 to examine Australia's balance between promoting innovation and protecting IP. The report includes the benchmarking of Australia's performance as a country offering a strong IP system using patent indices such as the index by Park (2008). The productivity commission went on to identify and recommend targeted changes that can further strengthen their patent system and bring them up to par with and differentiate their patent system from countries that offer similar levels of strength.

### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jwb.2020.101092.

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