Potential Value of Patents With Provisional Applications: An Assessment of Bibliometric Approach

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***Abstract*—This article used nine patent value indicators to compare the differences in the characteristics of U.S. patents for which provisional applications (PAs) were submitted and other patents without PAs (NPAs). The findings revealed significant differences in the average numbers of backward and forward citations, patent and nonpatent references, and patent claims, patent family size (number of patents and number of countries), and duration of examination between the two groups of patents granted between 2005 and 2017 by United States Patent and Trademark Office. Increasing trends were observed in the average number of backward citations and average percentage of patents renewed per year in both PA and NPA groups, whereas decreasing trends were observed in the average numbers of forward citations, countries, claims, and average duration of examination per patent and per year in PA and NPA groups. Differences in patent characteristics based on type and field were observed. This article also revealed more significant differences in PAs than in NPAs because of a larger number of pairs of fields. The results of this study confirmed that PAs have a stronger association with patent value and provided further justification for filing PAs, in addition to obtaining an early effective date for new inventions.**

***Index Terms*—Backward citations, forward citations, nonprovisional application (NPA), patent claims, patent renewal, patent value, provisional application (PA).**

I. Introduction

THE benefits of acquiring a provisional application (PA) have rendered it a necessary strategy for inventors to protect their intellectual property. A slight increase in the ratio of (PAs to nonprovisional applications (NPAs) has been observed among U.S. patents granted between 2005 and 2014 [1]. A PA allows inventors to secure an early filing date for the invention, with simplifies filing requirements and reduces patenting costs. After filing a PA, inventors are legally entitled to describe their inventions as having a "patent pending" for the following 12 months. PAs exist only in the U.S. Since June 8, 1995, the United States Patent and Trademark Office (USPTO) has allowed inventors to file a PA which is not required to have a formal patent claim or an oath or declaration. However, inventors must file an NPA within 12 months after filing a PA to prevent a PA from automatically being rescinded. During a 12-month period, inventors can evaluate the potential value of and market for their invention. Inventors prepare to file an NPA if they believe their invention has a high value. Therefore, inventors filing PAs first must complete a longer filing process to obtain granted patents than those filing NPAs.

Patents are valuable assets that are owned by inventors and assignees. Patent value is determined by stakeholders, including patentees, patent examiners, a third party, and other patent inventors. The original value is decided by the inventor; therefore, filing patents can be regarded as the next step after creating an invention. Patent examiners decide whether patents are granted. Only granted patents have potential value. However, a third party can challenge patent decisions and applications, thereby reducing the mistakes made by patent offices. Patent applicants purposefully opt for strategies that involve longer times and higher costs in the patenting process when they expect a higher patent value [2], [3]. The primary purpose of a PA is to enable an inventor to file an NPA within a year. The cost and time required for patenting an invention through PAs and NPAs are higher than those granted without using a PA. By filing a PA, inventors can protect their invention and take time to assess the value of their invention before they file an NPA. Therefore, we assume that patents claiming priority for a PA are more valuable than those for which NPAs have been made. This means that PAs have advantages in economic, technological, innovative, and social value associated with patents [4], [5]. The differences between the patent characteristics of PAs and NPAs in relation to patent value require examination.

The distribution in the value of granted patents is highly skewed [6]–[8], which explain why identifying valuable patents has become a pertinent research topic. Numerous studies have proposed patent value indicators and have focused on the link between indicators and patent value [5], [9]–[12]. The potential determinants of patent value are complicated [13]. In addition to the evaluation of the patent stakeholders, researchers are

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concerned with the association between a patent's characteristics and its value. Determining patent value from patent characteristics is easier than obtaining information about a patent's value from patent stakeholders or other methods outside the patent system. Therefore, the association between the patent characteristics and the patent value must be analyzed.

Numerous patent characteristics have been proven to have a positive association with the patent value [3], [5], [9], [10], [13]. However, the difference in values of patents with PAs and NPAs have not been considered and discussed. Inventors have been filing PAs for more than a decade, and a continual increase is observed in patents with PAs [1]; however, few studies have been conducted on PAs. Therefore, this article aimed to provide an improved understand of PA characteristics by examining the difference between the patent values of PAs and NPAs. Several indicators mentioned in the literature are used to examine whether the characteristics of PAs differ from those of NPAs through analyzing patent value, including backward citation (patent references and nonpatent references), forward citation (citations received), number of claims, patent family size, patent renewals, and duration of examination. The potential value of patents explored in this article are multiple, including technological, innovative, private, and economic value, because the association between various types of patent value and value indicators have been observed from numerous prior studies [3], [6], [9]–[12], [14]. In particularly, technological and economic value has been mentioned the most. In addition, differences in patent characteristics based on their field have been investigated. If the differences in characteristics have a positive correlation with patent value between PA and NPA, the possibility of a PA having higher patent value than an NPA increases. This helps patent applicants realize that filing a PA can be a valuable strategy. In addition to obtaining an early effective filing date, the potential increase in patent value incentivizes inventors to file PAs. Therefore, the results of this article exhibit practice implications. Research questions in this article are as follows.

1) Do NPAs and PAs exhibit differences in terms of characteristic patent values and field?
2) Which patent value-related characteristics have the strongest positive association with PAs?

This article is organized as follows. Section II provides a literature review of the patent characteristics with relation to patent value. Section III describes the research methods, including data collection, process, and indicators used. Section IV presents the findings of this article. Finally, Section V concludes this article.

II. Literature Review

Although being granted a patent signifies that new inventions satisfy requirements for this endeavor, not all patents are considered to have a similar or increasing value. Among the various types of patent value, the most basic is the economic value measured by the cost of obtaining a patent. Based on the amount of money that patentees invest, a high cost can be perceived as a proxy for identifying patents with a high value. The monetary value of a patent can be identified through the patent characteristics or through an assessment of the patentees [6]. Several monetary characteristics of patents have been used to determine the differences in value among patents, such as patent renewal, litigation, and financial market value [15].

Maintenance fees reflect the asset value of patents [10], with patent renewal decisions made by patentees revealing the economic value of granted patents [9]. The payment of maintenance fees or renewal fees is required to maintain the validity of granted patents. U.S. patent law regulates the payment of maintenance fees after 3.5, 7.5, and 11.5 years for utility patents. A granted patent signifies approval of the value of a technology. However, not all granted patents can maintain their value. Patentees are willing to pay maintenance fees to retain patents with values higher than maintenance fees [4]. Patents with the highest value can be renewed to full term with the largest accumulated renewal fees over time.

The concept of patent costs can also be applied to patent litigation. The value of litigated patents is considered higher than that of unlitigated patents because patentees should only litigate patents that are more valuable than the litigated costs [4]. Other possibly useful data for representing the economic value of patents include financial returns from licensing fees to patents [15], total stock value [16], [17], self-evaluation of patent inventors regarding the minimum prices that they demand from buyers [18], and research and development expenditure [8]. In addition, researchers have focused on identifying other characteristics that are positively related to patent value. With the exception of the aforementioned patent renewals, related studies about other patent value indicators used in this article are reviewed in this section, including citation- based indicators (backward citations and forward citations), claims, patent family size, and duration of examination.

A. Citation-Based Indicators

Forward citations refer to the number of citations received by patents over time, while backward citations are the number of references that patents cite. The cited and citing relationship that has been widely used to observe the evolution of scientific documents also fits the current focus on technological origin, development, and the influence of patents. Citation-based indicators are frequently used to present the economic [4], [19], business [14], monetary [11], and social value [5] of a patent. Numerous studies have reported a positive association between forward citations and the economic value of patents [10], [20], and between backward citations and patent value [10], [20].

New inventions rely on current technology and research. Therefore, inventors are required to list patent and nonpatent literature related to their inventions. The references cited for patents indicate the existing knowledge that can be claimed by the patent applicant [15]. The paths reveal knowledge about specific inventions and academic publications that relate to other patents. Nonpatent references represent research output from the scientific community. Patent references demonstrate the current technologies that are still useful for future inventions and inventors seek to improve and expand existing knowledge [21]. Differences between the inventions and current technology assist patent examiners in ensuring the novelty level of inventions. Therefore, backward citations affect decisions regarding patent granting and limit the scope of patent claims [22],

TABLE I
PATENT VALUE INDICATORS

Indicators	Types of patent value
Number of forward citations	Technological, innovative, economic, social [4][18][[19],[25]
Number of backward citations	Technological, economic[20][24]
Number of patent references	
Number of non- patent references	
Patent family size (Number of patents)	Technological, economic[10], [32]
Patent family size (Number of countries)	Technological, economic[10], [32]
Number of claims	Technological, economic[20][34]
Duration of examination (days)	Economic[35-37]
Patent renewal	Economic[9]

TABLE II
COMPARISON OF EIGHT PATENT CHARACTERISTICS OF NPAS AND PAS

Indicators	Type of patent	No. patents	Average number	SD	Range (Min.-Max.)	*t*	*p*
No. of backward citations	NPA PA	6500 6500	33.74 64.87	100.776 148.773	0-4587 0-3313	−13.967*	.000
No. of patent references	NPA PA	6500 6500	28.07 50.11	87.317 120.381	0-4421 0-3309	−11.946*	.000
No. of non-patent references	NPA PA	6500 6500	5.67 14.76	25.616 48.385	0-871 0-1154	−13.391*	.000
No. of forward citations	NPA PA	6500 6500	5.21 9.66	16.462 29.095	0-587 0-593	−10.735*	.000
Patent family size (No. of patents)	NPA PA	6500 6500	13.25 26.45	39.425 73.249	0-701 0-701	−12.790*	.000
Patent family size (No. of countries)	NPA PA	6500 6500	4.32 4.89	4.176 5.227	0-46 0-44	-6.761*	.000
No. of claims	NPA PA	6500 6500	15.48 19.30	10.730 14.113	1-150 1-241	−17.341*	.000
Duration of examination (days)	NPA PA	6500 6500	1200.16 1178.30	634.402 606.789	70-5975 85-5220	2.008*	0.045

Note: $^{*}p < 0.05$.

TABLE III
PERCENTAGES OF NPA AND PA PATENTS RENEWED

Patent renewal	NPA		PA		*p*
	No.	Percentage	No.	Percentage	
Maintenance fees have been paid	5935	91.3	5959	91.7	0.451
Maintenance fees are due	565	8.7	541	8.3	
Total	6500	100.0	6500	100.0	

Note: $p < 0.05$.

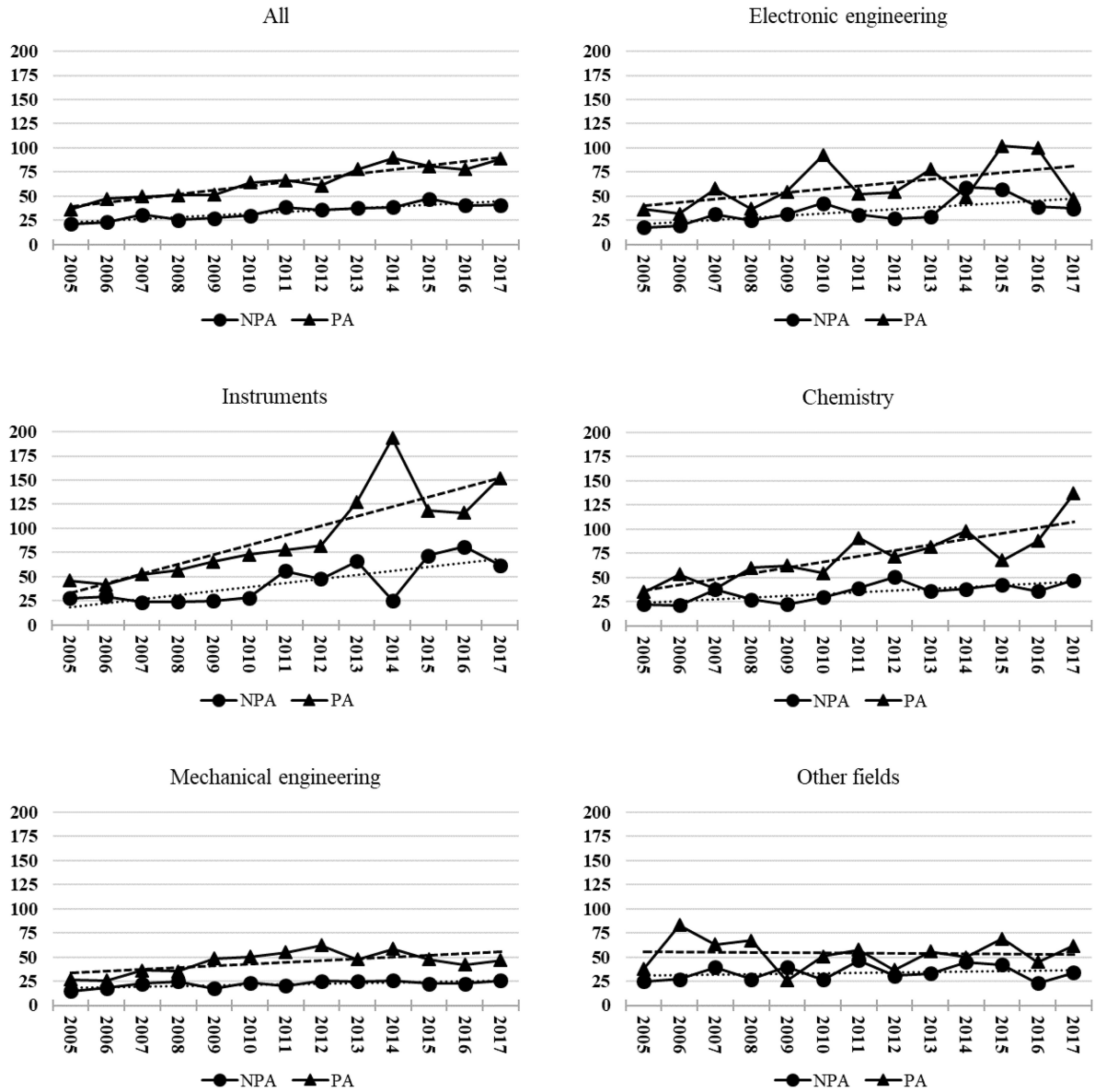

Fig. 1. Trends in the average number of backward citations between NPAs and PAs by year and field.

[23]. Regarding the relationship between backward citations and patent value, studies have revealed a positive correlation between backward citations and patent auction price [20], [24]. Kim *et al.* [17] posited that patents with fewer backward citations are vulnerable to patent infringement lawsuits. Numerous backward citations can become proxies for the protection of patents from invalidation claims. Kim *et al.* also noted that backward citations and patent family have a positive effect on the economic value of firms.

Forward citations reveal the technological effect of existing patents on future patents. Highly-cited patents are associated with technologies that have significant economic value [25] and social value [14]. Studies have indicated that companies with highly-cited patents are more advanced than their competitors [19]. Forward citations have been more widely used than backward citations to demonstrate patent value. This may be because few positive correlation has been observed between backward citations and patent value [10], [26], whereas findings from numerous studies have consistently indicated a positive correlation between the number of forward citations and patent value [5], [16], [20], [27]. The increasing popularity of forward citations is reflected in the increase of related indicators derived from them [19], [28]–[30].

B. Patent Family Size

To expand the scope of patent protection, patentees file patents in various countries. The first patent filing and subsequent filings that are linked by one or several common priority filings form a patent family [31]. Therefore, patent families represent the

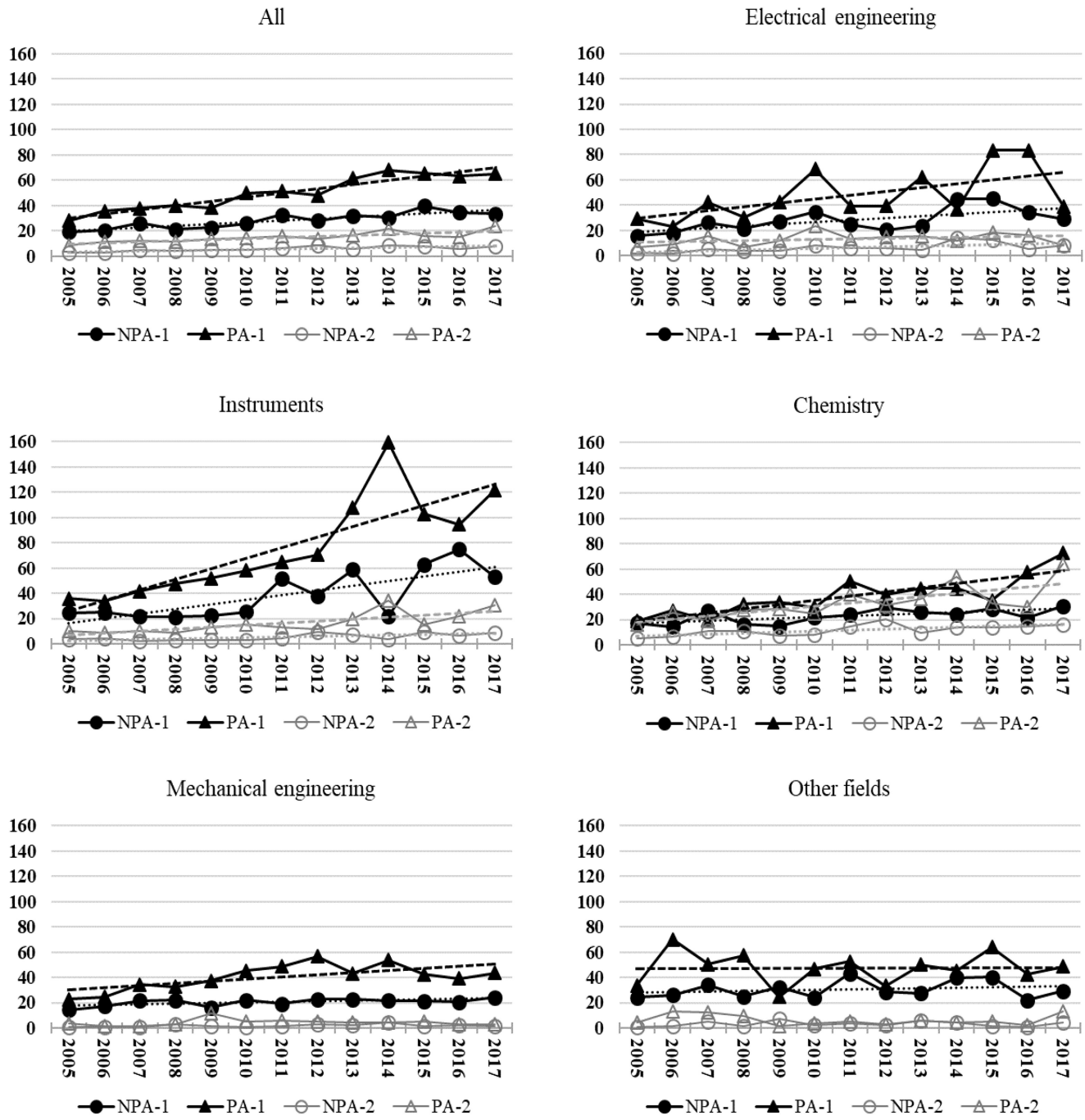

Fig. 2. Trends in the average number of patent and nonpatent references by year and field (note: 1 refers to patent references and 2 refers to nonpatent references).

international diffusion of technology. Because of the high costs associated with filing patents in different countries, patentees holding patents with large family sizes expect them to have substantial market and patent values [5]. The economic importance of the patent family has made it a strategy for the management of intellectual property rights. Studies have identified a positive correlation between patent family size in terms of the number of countries, in which patent protection is sought and patent value [10], [32]. However, the term "patent family" has not been defined consistently. Databases have employed different definitions of patent families [33]. Martínez [31] compared four of the most widely used patent family definitions and reported the different outcomes for a patent family based on these divergent definitions. The existence of various definitions of a patent family has led to divergent measures for determining patent family size. In addition to the number of patent applicants that form a patent family, which is a frequently used indicator [31], the number of countries where a patent is filed is considered to be representative of patent family size [6].

TABLE IV
COMPARISON OF NPAS AND PAS IN TERMS OF FIELD DISTRIBUTION OF PATENT REFERENCES

Patent reference by field		Electronic engineering		Instruments		Chemistry		Mechanical engineering		Other fields	
		NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA
Electronic engineering	N	16883	29929	2016	4661	348	422	801	1664	1013	1576
	%	84.9	84.4	7.2	7.7	2.6	1.9	5.8	5.4	4.5	4.5
Instruments	N	1192	2392	21873	46747	1015	1513	863	2221	1067	2148
	%	6.0	6.7	77.8	77.3	7.5	6.7	6.2	7.2	4.7	6.1
Chemistry	N	539	584	1041	2881	9805	18147	633	1879	910	1352
	%	2.7	1.6	3.7	4.8	72.5	80.9	4.6	6.1	4.0	3.9
Mechanical engineering	N	437	987	1052	2245	1032	1061	10237	21868	2336	3691
	%	2.2	2.8	3.7	3.7	7.6	4.7	73.7	70.5	10.4	10.5
Other fields	N	123	334	647	707	414	145	546	1503	15683	23910
	%	0.6	0.9	2.3	1.2	3.1	0.6	3.9	4.8	69.7	68.3
Cross	N	715	1242	1478	3239	905	1131	802	1895	1503	2354
	%	3.6	3.5	5.3	5.4	6.7	5.0	5.8	6.1	6.7	6.7
Total	N	19889	35468	28107	60480	13519	22419	13882	31030	22512	35031
	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
df		5		5		5		5		5	
ChiSq		115.494		218.171		581.316		87.130		53.035	
p		0.000		0.000		0.000		0.000		0.000	

Note: Cross refers to patent references assigned to two or more broad classifications.

C. Number of Claims

Patent claims refer to the scope of protection provided by the patent to exclude others from infringing upon a patentee's rights. Patent examiners review and compare prior art against patent claims to determine whether the patent claims define an invention that is novel and nonobvious. To define an invention that is innovative and nonobvious, patent applicants must include aspects in the claim that differ from those found in the prior art. Patent claims attempt to avoid overlapping with current technology, thereby justifying that the scope of claims should be wider. As a result the number of patent claims tends to be high. Patents with a large number of claims are considered to have high economic value. A positive correlation between the number of patent claims and patent value has been confirmed [34]. In addition, nonpracticing entities prefer to buy patents with a large number of claims [20].

D. Duration of Examination

The duration of examination refers to the length of time between the starting date, when an inventor files a patent application, and the termination date, which is the date when a patent is granted. A prolonged pendency time can have a negative effect on the patent application process, thereby delaying innovations from reaching the market and increasing the level of legal uncertainty in the patent system [35]. The potential factors that cause longer durations for patent examination include a large number of patent claims [36], large number of patent references [37], and increased workload for patent examiners, patent attorneys, and the USPTO [38]. However, findings regarding the cause of longer durations for patent examinations have been inconsistent. Harhoff and Wagner [37] and Wang and Lin [36] have reported that patents with higher value tend to be granted sooner than other patents, whereas [39] posited that patents with a relatively large number of references disclose more information to help patent examiners make decisions sooner.

E. Composite Value Indicators

Patent value is multifaceted. Different patent value indicators capture various aspects of patent value. Therefore, numerous studies have examined the association between multiple patent characteristics and patent value [4], [5], [9]–[12]. A higher explanatory power for patent value can be achieved through the combination of a few patent characteristics instead of a single characteristic. The most common patent characteristics that have been highlighted by researchers include forward citations [5], [9], [12], backward citations [10]–[12], patent family size [5], [10]–[12], number of patent claims [10]–[12], patent renewal (which is the decision of patentees to pay maintenance fees) [5], [9], and patent opposition [5]. Kapoor *et al.* [40] interviewed patent stakeholders to obtain their opinions regarding the association between patent characteristics and patent value.

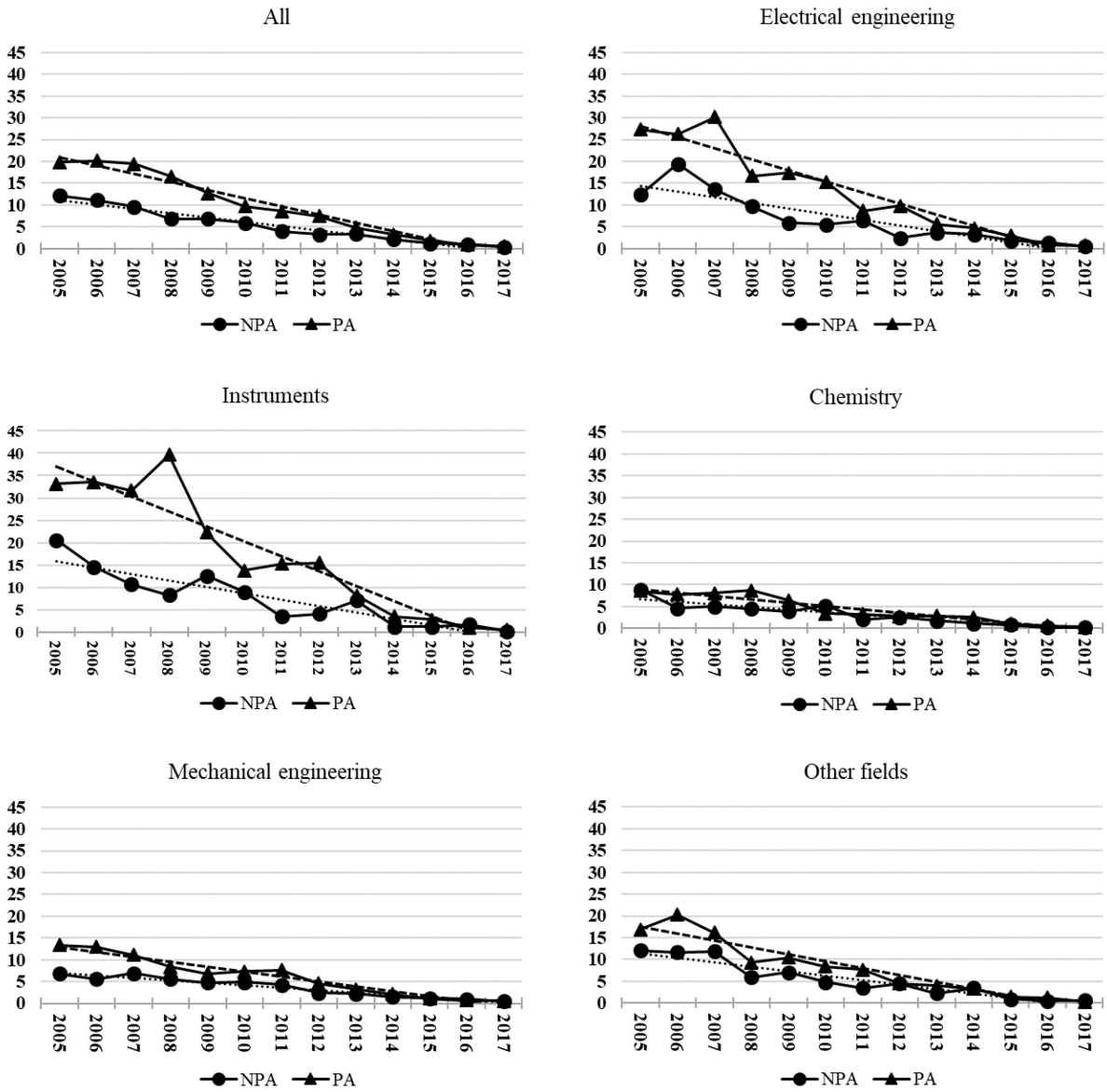

Fig. 3. Trends in the average number of forward citations by year and field.

Patent family size was considered as the optimal indicator for predicting patent value, followed by forward citations, patent renewals, backward citations, and the number of patent claims.

After referring to related studies, the following nine indicators for measuring patent value were selected: forward citations, backward citations, patent references, nonpatent references, patent family size, number of countries the patent family was derived from, number of patent claims, and duration of patent examination.

III. Methodology

A. Data Collection

A total of 3021001 U.S. patents issued between 2005 and 2017 from the USPTO application database were retrieved and divided into two groups according to patenting approach. One group consisted of patents claiming priority for PAs, whereas the other group consisted of other patents that did not claim priority for PAs. The PAs were identified through application numbers starting from 60. Bibliographic records for each U.S. patent collected for this article included the patent number, patent name, patent filing date, patent claims, references cited, patent issue date, and classification number assigned by the International Patent Classification (IPC) system.

To compare the patent characteristics by field, the patent classification numbers assigned to each patent were used to determine its field. The IPC system consists of 35 main classifications. To incorporate 35 classifications into several broad classifications, the latest version (the 2008 version) of the ISI-OST-INPI classification[1] was adopted. The ISI-OST-INPI classification was developed based on the IPC codes, which were developed in cooperation with the Fraunhofer Institute

[1] [Online]. Available: http://www.wipo.int/ipstats/en/index.html#data

TABLE V
COMPARISON OF BETWEEN NPAS AND PAS IN TERMS OF FIELD DISTRIBUTION OF PATENT CITATIONS

Patent reference by field		Electronic engineering		Instruments		Chemistry		Mechanical engineering		Other fields	
		NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA
Electronic engineering	N	7290	14640	1043	2527	144	318	312	441	378	609
	%	86.2	84.9	10.7	10.9	3.8	5.5	6.9	5.7	5.9	6.3
Instruments	N	358	966	6721	16617	268	254	286	639	264	539
	%	4.2	5.6	69.2	71.6	7.0	4.4	6.4	8.3	4.1	5.6
Chemistry	N	124	227	182	484	2529	4586	136	463	126	250
	%	1.5	1.3	1.9	2.1	66.2	78.8	3.0	6.0	2.0	2.6
Mechanical engineering	N	109	177	242	359	260	139	2980	4769	477	627
	%	1.3	1.0	2.5	1.5	6.8	2.4	66.4	61.9	7.4	6.5
Other fields	N	36	105	75	132	96	30	131	171	3743	5711
	%	0.4	0.6	0.8	0.6	2.5	0.5	2.9	2.2	58.4	59.3
Cross	N	544	1123	1455	3102	521	495	645	1224	1421	1887
	%	6.3	6.5	15.0	13.4	13.6	8.5	14.4	15.9	22.2	19.6
Total	N	8461	17238	9718	23221	3818	5822	4490	7707	6409	9623
	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
df		5		5		5		5		5	
ChiSq		29.723		58.102		330.204		87.130		42.205	
p		0.000		0.000		0.000		0.000		0.000	

Note: Cross refers to patent references assigned to two or more broad classifications.

for Systems and Innovation Research (ISI), the Observatoire des Sciences et des Technologies (OST), and the French patent office (INPI) (Schmoch 2008). The ISI-OST-INPI classification system incorporated 35 IPC codes into five broad classifications, namely electronic engineering, instruments, chemistry, mechanical engineering, and other fields (see Appendix). Using five broad classifications (fields) was more appropriate for observing the differences among patent characteristics than employing the 35 main classifications.

Approximately 86.6% of patents (2615752 patents) granted between 2005 and 2017 belonged to a single broad field. Each U.S. patent was assigned at least one IPC code. This led to the existence of partial patents spanning two or more broad fields, which were termed interdisciplinary patents. Among 2615753 patents, excluding interdisciplinary patents, electrical engineering patents accounted for the largest proportion (50.3%), followed by instruments (15.2%), mechanical engineering (14.8%), chemistry (14.5%), and other fields (5.2%), thereby indicating the uneven distribution of patents by field.

Because of the large number of patents granted between 2005 and 2017, a straightforward random sampling method was used to form sample patents for this study. Based on a total of 3021001 U.S. patents issued between 2005 and 2017, the present study required the inclusion of at least 9574 patents to achieve a 95% confidence level, with a 1% margin of error. A total of 100 PAs were randomly sampled from each of the five fields and each year. For the field comparison, interdisciplinary patents were excluded from the sample generation. Finally, 13000 patents met the requirements for the lowest number of sample size, and 6500 PAs and 6500 NPAs were divided into two sample groups.

To determine the difference between NPAs and PAs in terms of field self-citation rate in technological impact, patents cited by patents were divided into six broad categories by using their IPC codes. The process for categorizing a patent reference is the same as that used for the broad classification of each patent analyzed in this article. However, interdisciplinary patent references were categorized into an additional broad category. A single broad classification was assigned to a patent reference according to the broad classification with the largest number of relevant IPC codes. If a patent reference could be assigned to two or more broad classifications and each broad classification had the same number of IPC codes, then the patent was coded as an interdisciplinary patent reference. The same categorization process was used for assigning broad classification for each patent.

B. Patent Value Indicators

The literature related to patent value indicators has revealed that patent value can be identified through patent information within patent databases or by inventors [5]. Various indicators and approaches for ranking patent value generate various outcomes [5]. After examining the relationship between various

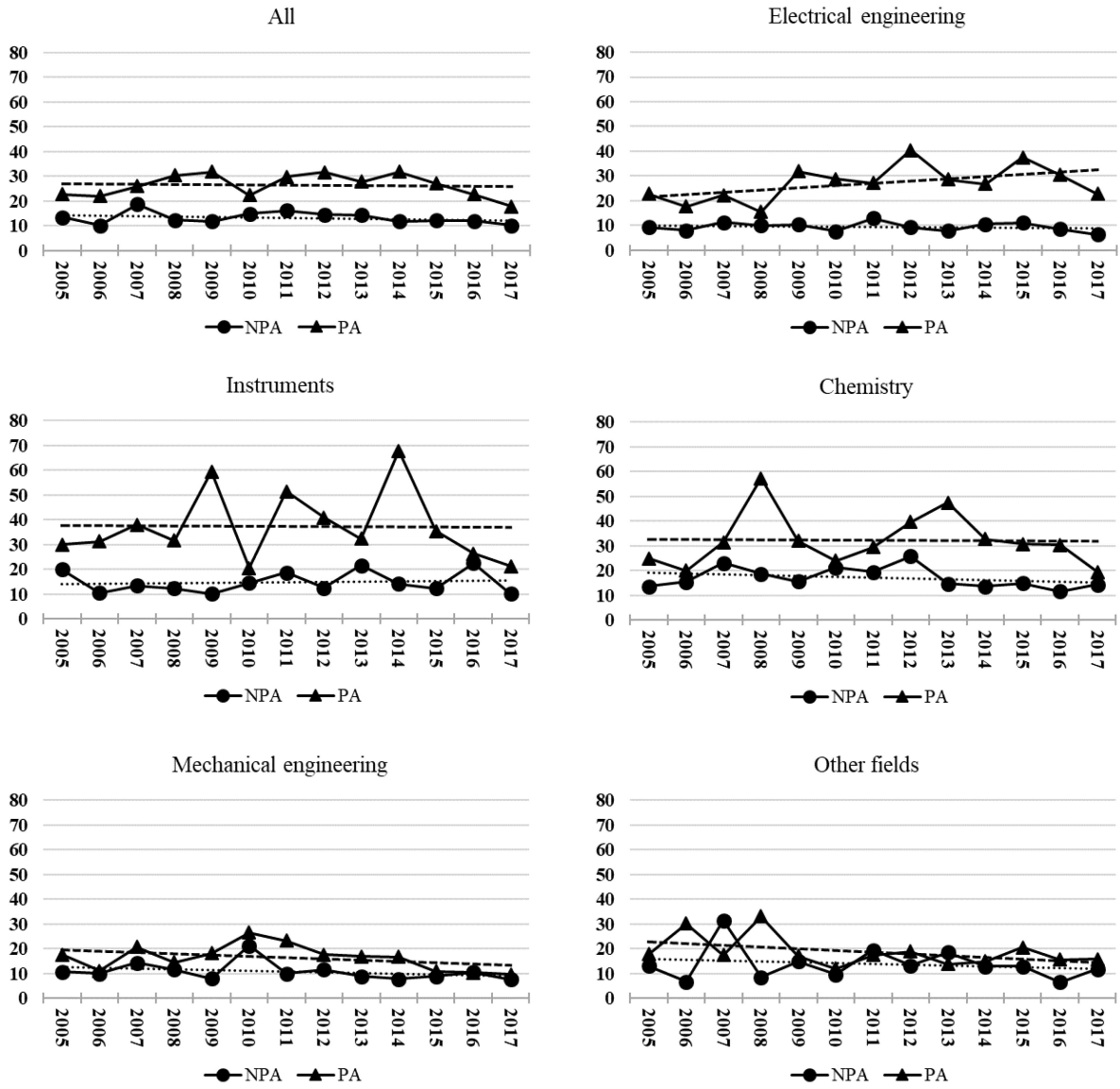

Fig. 4. Trends in the average number of patents within a patent family by year and field.

indicators and patent value observed by the studies mentioned in Section II, the availability of figures for measuring patent value were considered. As a result, nine indicators (see Table I) were used to measure patent value and compare the differences among patent characteristics between PAs and NPAs. Several hypotheses for the potential value of patents were formed. The larger the number of forward citation, the higher the potential value of patent. The same hypothesis applied to the numbers of backward citations, patent references, nonpatent references, patents, countries, and claims. Only duration of examination is the exception. The shorter the duration of examination, the higher the patent value. In addition, patent renewal is necessary for maintaining patent value.

The number of forward citations received by each patent was determined based on all the patents granted by the USPTO application database until August 28, 2018. Unlike [20], who counted the number of citations based on only the sample patents, in this article, the number of times that a specific patent was listed in the references of other patents was counted according to the references cited by all patents from the USPTO application database. In addition to the number of backward citations, patent references and nonpatent references were counted individually, based on references listed in the patent application. Two indicators were used to measure patent family size: the number of patents belonging to the same patent family and the number of countries where an invention was filed to expand the scope of protection. Certain members of the same patent family are granted patents from the same country, including divisional applicants or continuing applicants [6]. Therefore, the number of patents in a single patent family may not be equal to the number of countries, in which a given invention is protected. We revealed the patent family that each patent belongs to using patent numbers and Blazing Dawn Software's Family-izer.[2] The duration of examination refers to the period between the patent application date and issue date. The shorter the patent examination time is, the quicker a patent application

[2][Online]. Available: http://www.familyizer.com/index.html

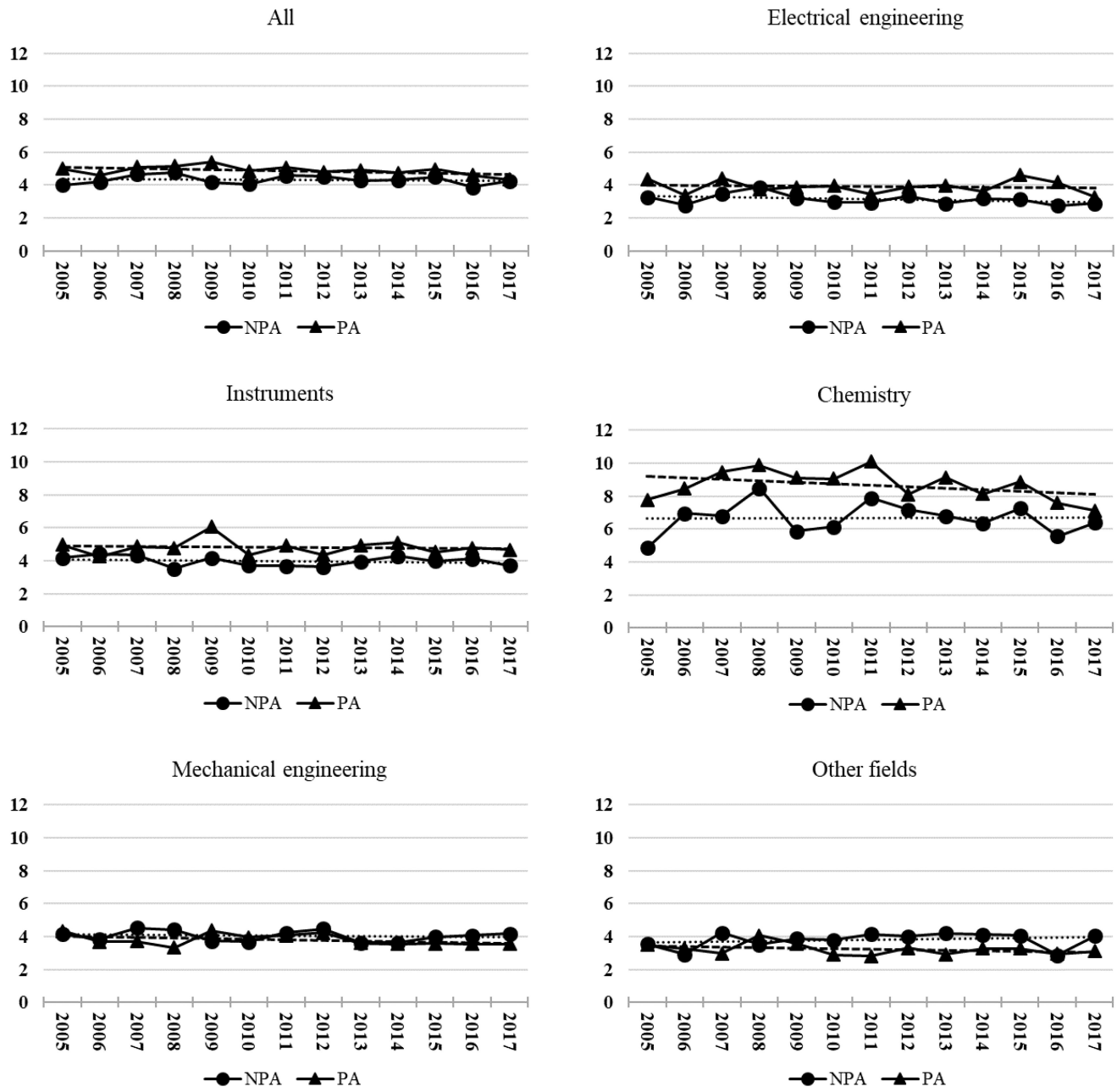

Fig. 5. Trends in the average number of countries covered by a patent family by year and field.

is granted. The USPTO website provides weekly updates to a list of invalid patents due to the nonpayment of maintenance fees. On the basis of the notice about the payable maintenance fees,[3] renewed patents were identified.

IV. Results

A. Differences in Characteristics Between NPAs and PAs

Table II presents a comparison of eight patent characteristics of NPAs and PAs obtained using an independent-samples t test. A significant difference was evident in the average number of backward citations for NPAs (mean [M] = 33.74, standard deviation [SD] = 100.776) and PAs ($M = 64.87$, SD = 148.773); t (12988) = −13.967, $p = 0.000$. A significant difference was also identified in the average numbers of patent and nonpatent references, forward citations, patent family size, countries, patent claims, and duration of examination between NPAs and PAs. Except for the duration of examination, the average values of seven indicators of PAs were higher than that of NPAs. In addition, no significant difference was evident in patent renewal between NPAs and PAs ($p = .451 > .05$), based on a chi-square test (see Table III).

[3][Online]. Available: https://www.uspto.gov/web/offices/com/sol/og/2018/week36/TOC.htm#ref2

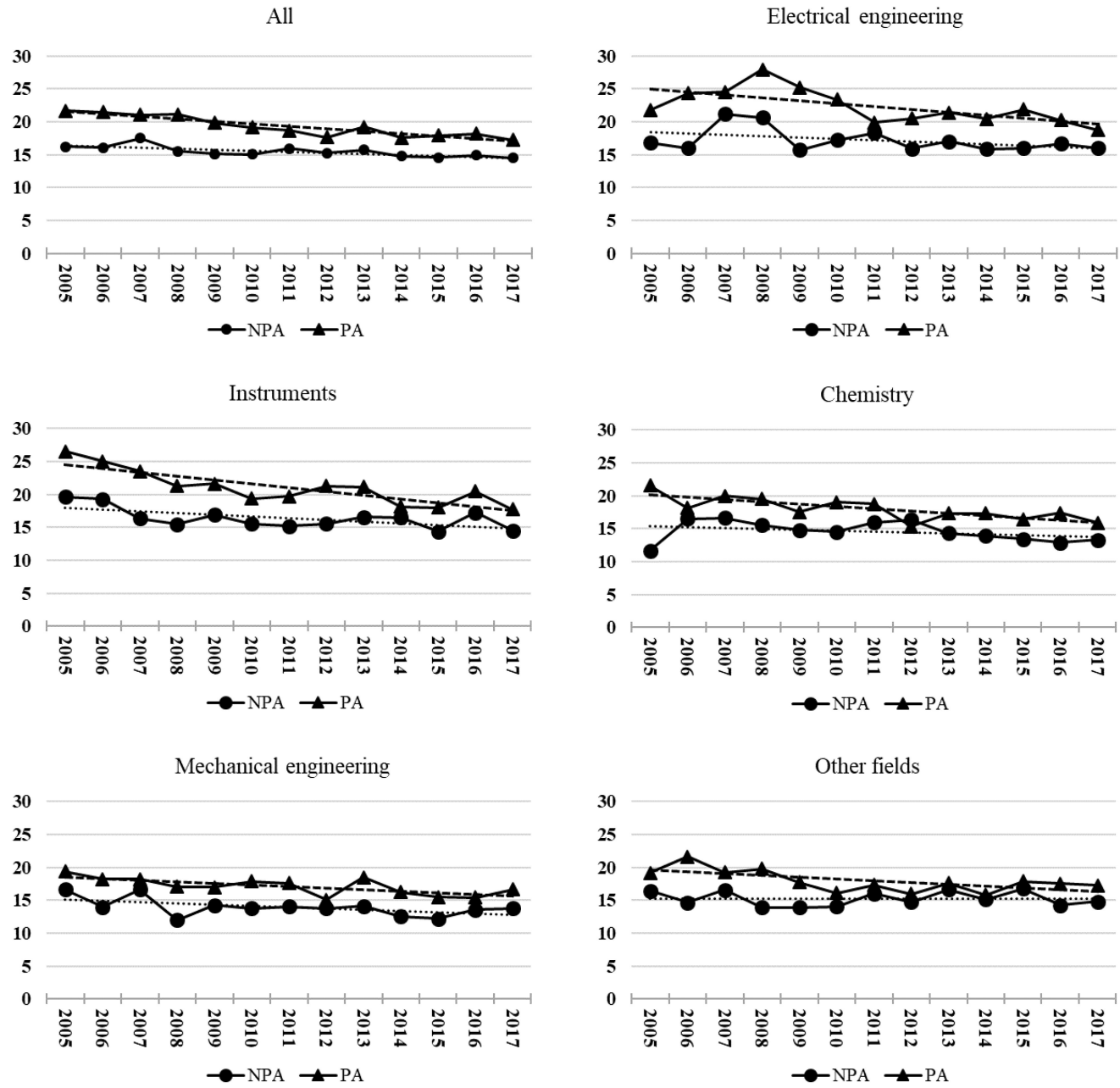

Fig. 6. Trends in the average number of claims by year and field.

B. Changes in Patent Characteristics by Year and Field

Fig. 1 compares the trends in the annual number of backward citations between NPAs and PAs (the upper left) and the individual trends in the five fields. The difference between NPAs and PAs in the average number of backward citations per year ranged between 8.9 and 37.5, with a gradually increasing gap. Both NPAs and PAs had increases in the number of backward citations per year. Regarding trends based on fields, upward trends in both NPAs and PAs and the increasing gap between them were observed in the fields of electronic engineering, instruments, chemistry, and mechanical engineering. The biggest gap between NPAs and PAs was identified in the instruments field in 2014. With the exception of electronic engineering in 2014 and "other fields" in 2009, the average numbers of backward citations for patents with PAs per year in each field were larger than those of NPAs.

Backward citations consist of patent and nonpatent references. Fig. 2 presents findings from the further analyses conducted to determine whether differences in trends exists between patent and nonpatent references. The average number of patents cited in patents with PAs per year was higher than those cited in patents with NPAs. The gap in the average number of patent references between NPAs and PAs per year increased. Similar results were observed for nonpatent references. The average number of nonpatent references cited in PAs was higher than those cited in NPAs, and the gap between NPAs and PAs increased slightly. However, the gap in the average number of

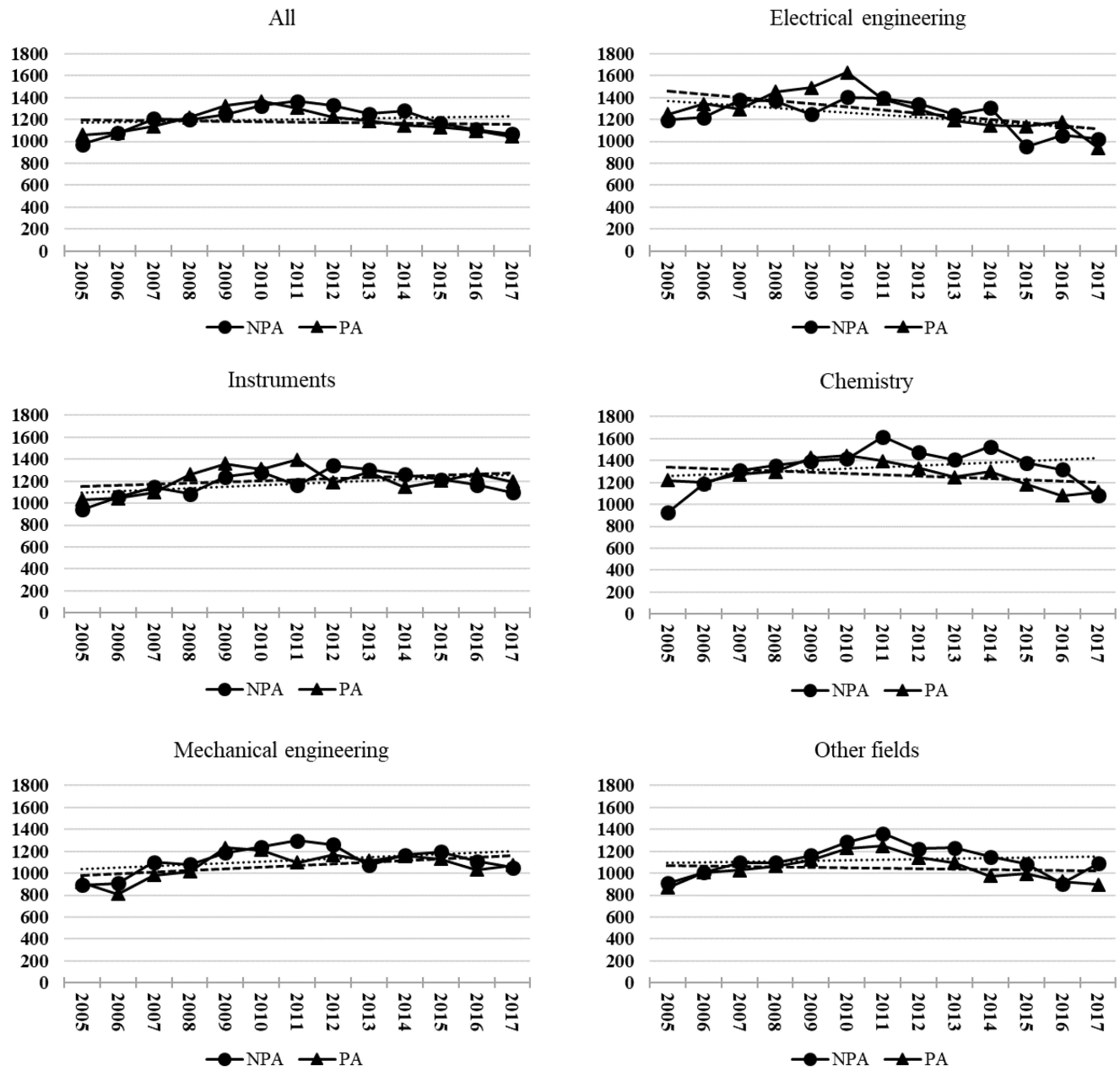

Fig. 7. Trends in the average number of days for patent examination by year and field.

patent references between NPAs and PAs was larger than that for the average number of nonpatent references, with the exception of the field of chemistry. Only PAs for chemistry-related inventions did not tend to cite more patent than the nonpatent literature. Patent references outnumbering nonpatent references resulted in a trend of backward citations similar to that of patent references.

To ensure that the degree of reliance on the technology from the same field, the field distribution of patents cited by the same patents was obtained. Up to 84.6% of patents cited by the same patents in the field of electronic engineering were from the same field. The highest technology self-reliance rate was observed in this field. The second-highest self-reliance rate was observed in the field of chemistry (77.8%), followed by instruments (77.5%), mechanical engineering (71.5%), and other fields (68.8%). Table IV compares the technology self-reliance rate between NPAs and PAs in each field. Excluding those in chemistry, patents with NPAs had a higher proportion of patents from the same field than those with PAs. Moreover, the results obtained using a chi-square test demonstrated that a significant difference ($p < 0.05$) was observed between NPAs and PAs in each field in terms of the field distribution of cited patents.

Fig. 3 presents trends in the number of forward citations. As expected, patents that were granted earlier had a larger average number of forward citations than those granted later because the cumulative citations received by patents are associated with time. A decreasing gap in the average number of

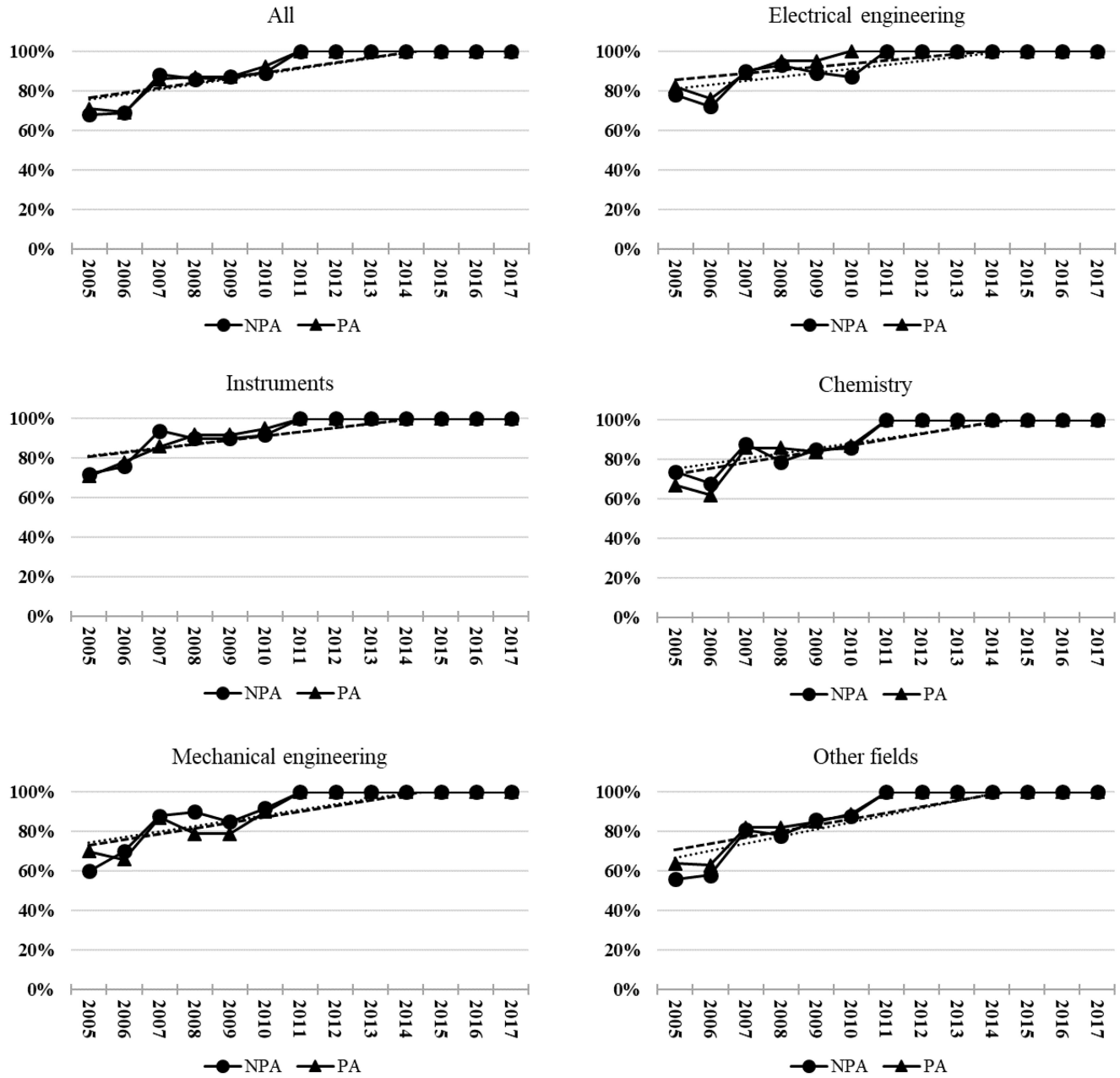

Fig. 8. Trends in the average percentage of patent renewals of NPAs and PAs by year and field.

forward citations between NPAs and PAs was observed in all the five fields. However, sharp decreasing trends in the average number of forward citations by year were identified in both NPAs and PAs for electrical engineering patents and those for instruments. Before 2012, the largest gap between NPAs and PAs was observed in instruments, followed by electrical engineering.

For the technological impact of patents by field, patents in all five fields had the highest technological impact on the patents in the same field. Patents in the field of electronic engineering (84.6%) had the strongest impact on patents from the same field, followed by those the field of chemistry (77.8%), instruments (77.5%), mechanical engineering (71.5%), and other field (68.7%). Significant differences were observed between NPAs and PAs in terms of technology self-impact in each field by using a chi-square test ($p < 0.05$). Table V shows that patents with PAs in instruments, chemistry, and other fields had a higher proportion of technological self-impact than patents with NPAs.

Fig. 4 presents the average number of patents that formed a patent family, wherein a PA added by year was higher than that per NPA. A slight decreasing trend in the average number of patents was observed in both NPAs and PAs. However, the patent family sizes of PAs were smaller than or similar to those of NPAs in mechanical engineering and other fields. The largest gap in the average patent family size between NPAs and PAs was observed in instruments, ranging between 3.8 and 53.8 patents. In terms of the number of countries where patents were

TABLE VI
DIFFERENCES IN CHARACTERISTICS BETWEEN FIELDS

Indicators	Type	EE (1)	Chem (2)	Instr (3)	ME (4)	Other (5)	F	Post hoc test NPA	Post hoc test PA
No. of backward citations	NPA	34.55	34.45	43.81	22.17	33.74	7.597*	1>4 2>4 3>4 5>4	1>4 2>5 3>1 3>2 3>4 3>5 4>2
	PA	61	72.03	92.47	44.8	54.07	20.014*		
No. of forward citations	NPA	6.63	3.15	7.27	3.66	5.32	15.641*	1>2 1>4 3>2 3>4 3>5 5>2	1>2 1>4 1>5 3>1 3>2 3>4 3>5 5>2
	PA	12.82	4.36	16.98	6.13	8.01	42.056*		
No. of patents	NPA	9.53	17.13	14.89	10.88	13.84	7.885*	2>1 2>4 3>1 5>1	1>4 2>4 2>5 3>2 3>4 3>5
	PA	27.16	32.3	37.49	16.47	18.82	19.263*		
No. of countries	NPA	3.14	6.66	3.98	4.05	3.8	149.152*	2>1 2>3 2>4 2>5 3>1 4>1 5>1	2>1 2>3 2>4 2>5 3>1 3>4 3>5 4>5 5>1
	PA	3.9	8.68	4.82	3.81	3.23	261.125*		
No. of claims	NPA	17.21	14.61	16.41	13.96	15.23	20.005*	1>4 1>5 2>1 3>2 3>4 3>5	1>2 1>4 1>5 3>2 3>4 3>5
	PA	22.34	18.03	21.07	17.12	17.93	34.317*		
Duration of examination (days)	NPA	1240.99	1338.14	1177.49	1120.25	1123.94	27.421*	1>4 1>5 2>1 2>3 2>4 2>5	1>3 1>4 1>5 2>4 2>5 3>4 3>5
	PA	1287.39	1270.45	1214.31	1072.93	1046.4	45.516*		

Notes: EE refers to electronic engineering, coded as 1; Chem refers to chemistry, coded as 2; Instr refers to instruments, coded as 3; ME refers to mechanical engineering, coded as 4; and Other refers to other fields, coded as 5.

sought for protection, smaller differences between NPAs and PAs were anticipated. As presented in Fig. 5, the differences between NPAs and PAs in the average number of countries per patent by year ranged between 0.1 and 1.2 countries. With the exception of the field of chemistry, which had the largest gap (between 0.7 and 3.3 countries), no obvious gaps was observed in the other four fields.

Fig. 6 reveals that the average number of claims per PA by year was higher than those per NPA. A decreasing gap was observed between NPAs and PAs. Decreasing trends and gaps were also observed in each field.

Fig. 7 shows the decreasing trend in the average number of days for examining patent applications between 2011 and 2017 for both NPAs and PAs. Similar decreasing trends were

TABLE VII
CORRELATIONS BETWEEN PAIRS OF INDICATORS BASED ON NPAS

	No.of patent references	No. of non-patent references	No. of Backward citations	No. of Forward citations	No. of patents	No. of countries	No. of claims	Duration of examination
No. of patent references	1	0.419**	0.973**	0.195**	0.302**	0.112**	0.132**	0.046**
No. of non-patent references		1	0.617**	0.050**	0.224**	0.173**	0.103**	0.119**
No. of Backward citations			1	0.181**	0.318**	0.141**	0.140**	0.070**
No. of Forward citations				1	0.148**	0.029*	0.159**	0.035**
No. of patents					1	0.412**	0.105**	0.039**
No. of countries						1	0.066**	0.218**
No. of claims							1	0.099**
Duration of examination								1

Note: $^{**}p < 0.001$.

observed in electrical engineering, chemistry, and "other fields." In particular, a substantial decrease was observed in the duration of patent examination for electrical engineering patents. A slight increasing trend was also noted for instruments and the field of mechanical engineering.

Fig. 8 shows that all the NPAs and PAs granted from 2011 to 2017 retained their validity. During the maximum 20-year life span, patentees must pay a maintenance fee after 3.5, 7.5, and 11.5 years. Therefore, it is impossible to determine whether patents granted less than 12 years ago were paid by their patentees. Some patents that were granted during earlier periods (2005–2010) are no longer protected by patent laws due to nonpayment of renewal fees. In other words, patentees require time to assess patent value.

C. Differences in Patent Characteristics by Field

To determine the differences in patent characteristics by field, an analysis of variance (ANOVA) was conducted to determine statistically significant differences in the characteristics of NPAs among the five fields. A significant difference was also observed in the characteristics of PAs in the five fields. To examine the differences between two fields, a Tukey post hoc test was conducted to make pairwise multiple comparisons. Table VI presents the results of the one-way ANOVA, indicating that a statistically significant difference is present in the average number of backward citations between fields [F (4, 6495) = 7.597, p = .000]. The results of the Tukey post hoc test for backward citations of NPAs revealed that the mean of mechanical engineering (22.17) was significantly lower than that of the other four fields. A statistically significant difference was observed between mechanical engineering and all other fields. No statistically significant differences existed between any two of the electronic engineering, chemistry, instruments, and "other" fields. Except the number of claims with significant differences that were identified in six pairs of fields in both NPAs and PAs, a higher number of pairs of fields had significant differences within PAs than they did in NPAs.

D. Correlation Between Indicators

Table VII presents correlations between pairs of indicators based on NPAs. A significant difference was observed in each pair of indicators. Most pairs of indicators had weak correlations, with correlation coefficients lower than 0.3. Medium and high correlations were observed between two indicators from the same category, such as patent references and backward citations (0.973), nonpatent references and backward citations (0.617), and number of patents and number of countries (0.412). Table VIII shows the correlation between pairs of indicators based on PAs. A medium correlation was noted between patent

TABLE VIII
CORRELATIONS BETWEEN PAIRS OF INDICATORS BASED ON PAS

	No.of patent references	No. of non-patent references	No.of backward citations	No.of forward citations	No.of patents	No.of countries	No.of claims	Duration examination
No. of patent references	1	0.455**	0.957**	0.124**	0.328**	0.167**	0.105**	0.036**
No. of non-patent references		1	0.693**	0.054**	0.190**	0.200**	0.088**	0.078**
No. of backward citations			1	0.118**	0.327**	0.200**	0.114**	0.055**
No. of forward citations				1	0.169**	0.094*	0.150**	0.043**
No. of patents					1	0.465**	0.087**	0.033**
No. of countries						1	0.091**	0.073**
No. of claims							1	0.118**
Duration of examination								1

Note: $^{**}p < 0.001$.

TABLE IX
LOGISTIC REGRESSION ANALYSIS

Independent variable	ß	S. E.	Wald	df	Sig.	Exp(ß)	95% C.I. for Exp(ß) lower	upper
Number of patent references	0.001	0.000	6.666	1	0.010*	1.001	1.000	1.001
Nonpatent references	0.008	0.001	72.560	1	0.000*	1.009	1.007	1.010
Number of citations	0.008	0.001	40.495	1	0.000*	1.008	1.005	1.010
Patent family (No. of patents)	0.004	0.001	42.598	1	0.000*	1.004	1.003	1.005
Patent family (No. of countries)	-0.008	0.005	2.965	1	0.085	0.992	0.983	1.001
Number of claims	0.024	0.002	184.866	1	0.000*	1.024	1.020	1.027
Duration of examination	0.000	0.000	25.405	1	0.000*	1.000	1.000	1.000
Patent renewal	0.038	0.064	0.345	1	0.557	1.038	0.915	1.178
Constant	-0.389	0.054	52.482	1	0.000	0.678		

Note: $^{*}p < 0.05$.

references and number of patents (0.328) and between backward citations and number of patents (0.327).

To determine the existence of a significant relationship between the eight characteristics and PAs, a logistic regression was conducted. Because the number of backward citations is associated with the number of nonpatent references and patent references, the two types of references have different indications; the number of backward citations was excluded from this logic model. Table IX shows that the combination of eight independent variables has an explanation power of 60.4%. Excluding the two variables, namely the number of countries covered by a patent family and patent renewal, all six variables were significantly and positively associated with PAs ($p < 0.05$). The number of claims is an independent variable with the highest explanatory power ($\beta = 0.024$). Table X shows the logistic regression analysis of patents in each field, which indicated that only the number of

TABLE X
COMPARISON OF EXPLANATORY POWER OF EIGHT VARIABLES FOR BEING PAS BY FIELD

Independent variables	All	Electronic engineering	Instruments	Chemistry	Mechanical engineering	Other fields
Number of Patent references	X				X	X
Number of nonpatent references	X		X	X		
Number of citations	X	X	X		X	X
Patent family (No. of patents)	X	X	X	X		X
Patent family (No. of countries)				X*	X	
Number of claims	X*	X*	X*	X	X*	X*
Duration of examination	X			X		X
Patent renewal						
Explanatory power	60.4%	62.3%	62.4%	64.3%	63.9%	58.8%

Note: X refers to a variable significantly positive with PA; * refers to the most explanatory variable.

claims is the common variable among fields; fields are different in terms of several other aspects.

V. CONCLUSION

The results of this article confirm the significant differences in certain patent characteristics between patents with NPAs and PAs. Nine characteristics (variables) relevant to patent value were used to determine whether NPAs differs from PAs. The results measured by eight indicators, excluding patent renewal, revealed that NPAs differ from PAs in the average numbers of backward and forward citations, patent and nonpatent references, patents within the same patent family, countries where the patent is protected, claims, and duration of examining patent applications. PAs had higher average numbers of backward and forward citations, claims, patents, and countries. Moreover, PAs required lower than the average durations for examining patents than NPAs did. These differences between NPAs and PAs can help PAs serve as a new indicator for classifying patents and identifying patents with greater value.

Although this article did not measure the correlation between patent value and patent value indicators, possible reasons for the differences in characteristics between PAs and NPAs may be related to patent value, because applicants were willing to pay additional costs to expand the scope of protection for high value patents. In such a situation, anticipating a larger patent family size, with higher numbers of patents and countries, is rational. This may partially explain why a slightly higher positive correlation was observed between numbers of patents and countries in PAs. Those applying for PAs must prepare patent claims and backward citations. Patent claims are a core feature of patents and play a key role in defining the scope of protection sought in a patent application. The patent claims state the extent of the patent holder's rights. Therefore, if anyone violates these rights, they are infringing on the patent. Backward citations are essential for highlighting the current technology and scientific knowledge and helping the patent examiner determine whether the invention meet the requirements for patenting. If evidence from these references indicates that the invention already exists, a patent will not be granted. However, when a considerable amount of references that are relevant to the invention are listed, it becomes difficult to expand the scope of the claim. Therefore, a tradeoff exists between the number of references cited and that of claims. The findings of this article are also consistent with the low correlation between the number of claims and that of backward citations [13]. In addition, according to the nature of claims, patentees benefit from patents with a large number of claims that are granted a large scope of protection. High value patents feature a large number of claims [20], [34]. The number of claims in this article was the most influential variable, which was significantly related to patents with PAs.

The role of references in patent applications differs from that of references in scientific publications [41]. The findings confirm that patents cited more patents than nonpatent references; thereby indicating that current technology has a greater effect on new technology than the extant research. References are used to prove the novelty of a patent. Decisions on listing references should be made with caution. In particular, references are examined and revisited by patent examiners. Therefore, when a patent is cited by other patents, its technological impact can be ensured. Patents with a large number of forward citations are considered valuable and influential. Although the distribution of forward citations received by patents is highly skewed, the positive correlations between forward citations and patent value have been widely emphasized and regarded as the most useful indicator of a patent's value [6], [13], [22], [40]. Although patents with PAs and NPAs in each field primarily cited patents from the same field and had the highest technological impact on patents from the same fields, the differences were observed between PAs and NPAs in terms of the field self-reliance rate and technological impact.

Patent applications rely on foundations established by existing patents and scientific publications. The cumulative scientific knowledge and technology may reflect an increasing trend in the average number of patents and nonpatent references cited by patents. Therefore, it is reasonable to assume that patent applicants and examiners must spend more time to search for related scientific publications and patents. The increase in the number of backward citations increases the time required for patent examiners to review patent applicants. However, a slight decreasing trend in the length of time spent examining patent applications was observed in both PAs and NPAs. This is in line with the findings that numerous possible factors affect the duration of examination, such as administrative efficiency, workload for each patent examiner, and requests for quick processing [5].

Patent renewal is an exception among the nine indicators used in this article. The findings indicate no significant differences in patent renewal between NPAs and PAs. Most patents analyzed in this article were regarded as valuable assets by patentees because they were willing to pay maintenance fees. US patents are granted a period of 20 years from the filing date of a patent application, subject to the payment of maintenance fees. Patentees must pay maintenance fees three times if they wish to hold an exclusive 20-year patent. Renewal fees are one of the possible factors affecting applicant behavior. High and low entry and renewal fees have advantages and disadvantages [42]. High renewal fees encourage inventions with high quality and value, whereas low fees lead to almost all inventions being filed [43]. Higher value inventions, which rely on high costs, receive longer patents [44]. Therefore, studies have suggested that the optimal renewal fees must rise sharply with the patent age [44], [45]. Patents granted recently require time to prove the changes in their value from the perspective of patent renewal. Therefore, we cannot ensure whether patents granted less than 13 years will continue to maintain their validity. This is a major limitation of this article.

This article also had differences in characteristics based on fields. Except "other fields" with only three IPC codes, the increase in the number of patents in the field of technology may lead to more patent references listed in newer patent applications. In particular, half of US patents were related to electrical engineering. However, the average number of backward citations per electrical engineering patent was not higher than that for patents in other fields. The field of instruments showed the most substantial changes in trends regarding the number of backward citations and forward citations. Patents for instruments were found to have longer-lasting technological influences on new inventions than other patent types. In contrast to instruments patents, the technological influence of earlier chemistry patents was limited, with less forward citations and patent references compared with nonpatent references. The increasing growth of patents has also led to a decreasing trend in the number of claims. Increases in related patents render it difficult for newer inventions to be novel and nonobvious. Technological differences may account for the differences among fields. For instance, [13] noted that technology-specific practices and the evolution of technology affect the number of claims in different fields. Future studies should further examine the reasons for differences in patent characteristics.

Studies have reported that each indicator used in this article is associated with patent value. However, nonsignificant differences were also reported in a few studies, such as for backward citations [26], number of claims [13], and duration of examination [37], [39]. The inconsistent findings regarding the correlation between patent value indicators and actual patent value cannot support our claim that patents with PAs are more valuable than those with NPAs. Furthermore, a weak correlation was noted between the major pairs of value indicators. The number of backward citations is the sum of the number of patent references and number of nonpatent references. Therefore, a higher correlation can be observed between backward citations and patent references and between backward citations and nonpatent references. To understand the effect the division of patent and nonpatent references has on the analyzed results, the numbers of backward citations, patent reference, and nonpatent references were simultaneously considered. The findings of this study are consistent with those reported by [6], wherein various indicators (variables) were loosely correlated. This indicates that although individual indicators have positive correlations with patent value, a positive association between various types of indicators cannot be inferred. Each value indicator has its characteristics. High value patents that were identified using various value indicators were not the same. This finding highlights that patent value cannot be identified using only one or a few indicators.

Because the results of this article indicates that NPAs were different from PAs in terms of characteristics and patents with PAs had a stronger association with patents than NPAs, whether inventors prefer using PAs was examined. Among 32886 inventor names included in the patent sample, only 1.0% inventors (316 inventors) filed both PAs and NPAs. The number of inventors filing at least one PA (16848 inventors, 51.2%) was higher than that those filing at least one NPAs (15722 inventors, 47.8%). This observation revealed that inventors generally file patents with either PAs or NPAs, thus indicating that most inventors have a preference between PAs and NPAs. However, most inventors are associated with only one invention from the patent sample. Filing a PA has advantages and disadvantages. The advantages of PAs must be demonstrated. The cost of filing patents and potential value of patents affect the PA filing decisions of patent applicants. Although this article does not validate that patents with PAs are decisively more valuable than those with NPAs, it indicates the differences between patents with PAs and NPAs in terms of characteristics related to patent value. This observation indicates that patents can be categorized based on PAs and NPAs. Moreover, a slightly higher number of inventors who filed PAs may encourage other patent applicants to file PAs, in particular, when they are confident of the potential values of their inventions. Because of the lack of research on PAs, more future studies must focus on tracking the trend and characteristics of patents with PAs. Although this article is a preliminary research on PAs and patent value, a lot of findings of this article help

APPENDIX
ISI-OST-INPI CLASSIFICATION

Field number	Broad field	Field
1	Electrical engineering	Electrical machinery, apparatus, energy
2		Audio-visual technology
3		Telecommunications
4		Digital communication
5		Basic communication processes
6		Computer technology
7		IT methods for management
8		Semiconductors
9	Instruments	Optics
10		Measurement
11		Analysis of biological materials
12		Control
13		Medical technology
14	Chemistry	Organic fine chemistry
15		Biotechnology
16		Pharmaceuticals
17		Macromolecular chemistry, polymers
18		Food chemistry
19		Basic materials chemistry
20		Materials, metallurgy
21		Surface technology, coating
22		Micro-structural and nano-technology
23		Chemical engineering
24		Environmental technology
25	Mechanical engineering	Handling
26		Machine tools
27		Engines, pumps, turbines
28		Textile and paper machines
29		Other special machines
30		Thermal processes and apparatus
31		Mechanical elements
32		Transport
33	Other fields	Furniture, games
34		Other consumer goods
35		Civil engineering

researchers and patent practitioners further understanding more PA issues and as a foundation to do extent research.

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