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An investigation of patent-intensive industries and government development strategy: evidence from China

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Abstract

Purpose – The number of patents in China has grown rapidly in recent years. The purpose of this paper is to investigate how patents impact economic development in China.

Design/methodology/approach – This paper developed an empirical model by using panel data of 42 China's patent-intensive industries to investigate the economic contribution made by Chinese patent-intensive manufacturing industries.

Findings – This paper found that the intensity of valid patents is strongly positively related to economic growth. The intensity of yearly added patents presented an inverse U-shaped and a U-shaped curve with the economy made by China's patent-intensive industries. The correlativity mainly depended on whether the patent intensity converges near the economic indicators. Meanwhile, from the perspective of input–output efficiency, for China's patent-intensive industries, R&D institutes were overinvested, followed by R&D intensity and R&D staff.

Originality/value – Investigating patent influence on economic development is quite complex research. Existing studies have mainly focused on patent protection in legal systems, but have not provided a definitive answer to what the real influence is. This study sought to narrow this gap from the patent economy perspective.

Keywords Patent-intensive industry, Economic contribution, Government strategy, China

Paper type Research paper

1. Introduction

During the past 50 years, patents have been given more attention in developed and developing countries worldwide. In 1970, 35 founding members, including Germany, France, the UK, Switzerland and Brazil *et al.*, signed the Patent Cooperation Treaty (PCT). During the past 51 years, the PCT members have increased to 153 contracting states. To attract foreign technology transfer and physical investment, China launched its first patent law in 1984 and signed PCT in 1994. With the formulation and implementation of the Outline of the National Intellectual Property Strategy issued in 2008, China's domestic

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invention patent applications increased from 8,558 (1986) to 1,400,661 (2019), over 163.67 times. In addition, PCT applications increased 561.81 times from 105 (1994) to 58,990 (2019) and 2019 is the first year that China surpassed the USA to be the country with the largest number of international patent applications in the world. At the same time, China's gross domestic product (GDP) has been steadily increasing, from breaking RMB1tn in 1986 to more than RMB110tn in 2021, an almost 110-fold increase. With the sharpest growth in patent applications in the world, the question of what the real relationship between patents and economic growth is has become a hot topic and has drawn much attention from researchers.

Many previous studies have pointed out that patents can play a significant role in encouraging innovation, product development and technical changes (Park and Ginarte, 1997; Ldris, 2003, Kim *et al.*, 2018). Maskus and McDaniel (1999) considered how the Japanese patent system (JPS) affected postwar Japanese technical progress. The JPS over the estimation period of 1960–1993 evidently was designed to encourage incremental, adaptive and radical innovation and the diffusion of technical knowledge to the economy. In addition, from the international trade perspective, Chu and Peng (2011) found that strengthening patent protection could increase economic growth by using a two-country R&D-based growth model. Specifically, many researchers have discussed interdependent channels through which technology is transferred across borders, such as international trade in goods and services, foreign direct investment (FDI) with multinational enterprises and contractual licensing of technologies and trademarks (Mansfield, 1994, 1995; Maskus and Penubarti, 1995; Park and Lippoldt, 2008; Awokuse and Yin, 2010; Khoury and Peng, 2011). In these studies, developed countries driven by innovation have always advocated for strong patent protection, especially when there is market expansion. However, most developing countries attempt to find an optimal balance between strengthening patent protection and supporting domestic industries (Park and Lippoldt, 2008).

On the other hand, some researchers have published negative opinions about patents' economic influence. Mazzoleni and Nelson (1998) reviewed theories of the relationship between patent rights and economic development. They found that there is a reason for concern that stronger patent protection might hinder rather than stimulate technological and economic progress. Janjua and Samad (2007) also provided evidence that patent systems did not necessarily contribute to economic growth in middle-income developing countries, for example, Pakistan. Strong patent protection might cause inflationary pressure, unemployment and an imbalance of payment, reducing knowledge spillovers and raising business and innovation costs (Panagopoulos, 2009; Kim *et al.*, 2012).

In fact, the effectiveness of patent protection in economic development depends considerably on particular circumstances in selected countries. While researchers are devoting more attention to this issue, evidence from data is fragmented and somewhat contradictory, in part because many of the concepts involved are not easily measured (Maskus, 2000). Even so, previous studies have put too much emphasis on the question of whether countries should strengthen their patent protection, rather than switching their research angles to discuss patents' real economic influence.

In 2012, the United States Department of Commerce issued an official report titled *Intellectual Property and the U.S. Economy: Industries in Focus* (hereafter, the 2012 US report). The report identified the industries that rely most heavily on patents and estimated their contribution to the US economy. It generated considerable interest and energized other organizations to produce similar studies. In 2013, the Office for Harmonization in the Internal Market and the European Patent Office (EPO) joined forces to quantify the contribution of patent-intensive industries to the European Union (EU) economy and published a report titled *Intellectual property rights (IPR)-Intensive Industries: Contribution to Economic Performance and Employment in the European Union* (hereafter, the 2013 EU report). Both the USA and EU are committed to ensuring that the latest data are available to all those who need to understand the importance of patents, so the USA updated its studies in 2016 and 2022, respectively, and the EU updated its studies in 2016 and 2019, respectively. These six reports have all demonstrated the phenomenon that patent-intensive industries are providing remarkable contributions to the US and EU economies, including in GDP, employment and international trade. More importantly, patent-intensive industries appear to have coped better with the severe economic crisis than the worldwide economy.

In 2016, China National Intellectual Property Administration of the People's Republic of China (PRC) (used to be named the State Intellectual Property Office, hereafter, CNIPA) released a report (hereafter, the Chinese report) and compiled a catalogue of China's IPR intensive industries including eight categories of Chinese industries: information equipment manufacturing, software and information technology, transportation equipment, intelligent manufacturing equipment, biopharmaceutical, new functional materials, energy-saving and environmental protection and resource recycling. The contributions made by these patent-intensive industries to the Chinese GDP (gross industrial production) was accounting for 11.0% during the period from 2010 to 2014. They employed more than 26.31 million people, accounting for 3.4% of China's employment population. On September 22, 2021, a new goal proposed by the "Guidelines for Building a Powerful Country with Intellectual Property Rights (2021-2035)" that by 2025 the added value of patent-intensive industries shall have accounted for 13% of GDP and the number of high-value invention patents per 10,000 people will reach 12. Viewed from more specific contents, the guidelines are government policies not only for intellectual property rights protection but also for industry development. Moreover, according to a joint announcement by CNIPA and the National Bureau of Statistics of China in 2022, the added value of China's patent-intensive industries reached RMB12.13tn in 2020, up 5.8% year on year (excluding price factors), which was 3.1 percentage points higher than the current GDP growth rate in the same period. Compared to non-patent-intensive industries, China's patent-intensive industries presented six characteristics, including highly resilient development and driving economic growth under the impact of COVID-19, good economic benefit and rapid growing industrial profit rate, strong innovation ability and a further increase of the proportion of new product sales revenue, high-intensity investment in innovation and continuous increase in R&D and manpower investment, steadily increased employment and labor productivity, as well as high average wage income of employees which was similar to those in the USA and EU.

Given the significant influence of these patent-intensive industries, the Chinese Government has two different governance strategies. One strategy is "supportive policy." The government pays attention to high-tech industries (which are not included in the list of patent-intensive industries) and pushes incentive policies to let them in, such as patent subsidies, R&D deduction policy and tax preference policy. The other strategy is "enhancement policy." The government inputs more resources to patent-intensive industries because they have a higher probability of improving Chinese global industry competition. For example, CNIPA is trying to create industry-fostering policies for patent-intensive industries. However, the choice of governance strategies mainly depends on the selected industry itself.

In addition to the reports published by governments, literature related to patent-intensive industries focuses on three main issues: (1) measuring the scope, management capabilities, innovation efficiency, and innovation performance of patent-intensive industries based on different nations or regions (Shan *et al.*, 2018; Li and Wang, 2020; Chen *et al.*, 2022); (2) analyzing the economic contribution of patent-intensive industries (Jiang *et al.*, 2014; Li and Chen, 2017); (3) policies for patent-intensive industries development and related institutions

(Zhang and Li, 2019). Existing studies view patent-intensive industries as a whole analysis object, which ignores the difference between patent-intensive industries and the policies applied to them. Moreover, the conclusions and suggestions of previous studies may be limited or unsuitable because China is now in a stage of high-quality economic development.

Our study focused on China's patent-intensive industries, attempting to measure their economic contributions quantitatively. First, we reviewed the US and EU definitions. Then, we directly used CNIPA's patent-intensive industry catalogue released in 2016 and investigated their economic indicators including GDP, main business revenue (MBR) and export revenue (MR). Second, we developed a series of regression models to explore the relationship between patent intensity and economic indicators. Lastly, we discussed which kind of patent-related policy was appropriate to promote industrial economic development.

The research results show that the development of China's patent-intensive industries is extremely unbalanced. Economic performance varies with the specific industry, whereas some of them show little advantage compared with non-patent-intensive industries. The intensity of valid patents presents a positive linear relationship with economic indicators. However, for the intensity of yearly added patents, the situation becomes complex. There is an inverse U-shaped curve and a U-shaped curve among different industries. Finally, the results indicate that there is a large amount of room for improvement in the input–output efficiency of patent creation in China.

In terms of the relationship between patents and economic development, traditional research from the legal scheme perspective still cannot provide a definite answer whether strong patent protection is necessary. By contrast, this study provides new insights into this relationship from an industrial economic perspective and demonstrates the relative advantage of China's patent-intensive industries, enhancing our understanding of patent schemes and providing better information for policymakers in creating industry policies.

This paper is structured as follows. Section 2 provides a clear definition of patent-intensive industries and includes the catalogue of China's patent-intensive industries. Section 3 describes the research data and methods, followed by the research results in Section 4. Section 5 contains a discussion followed by the conclusion in Section 6.

2. Patent-intensive industries

2.1 Definition of patent-intensive industries

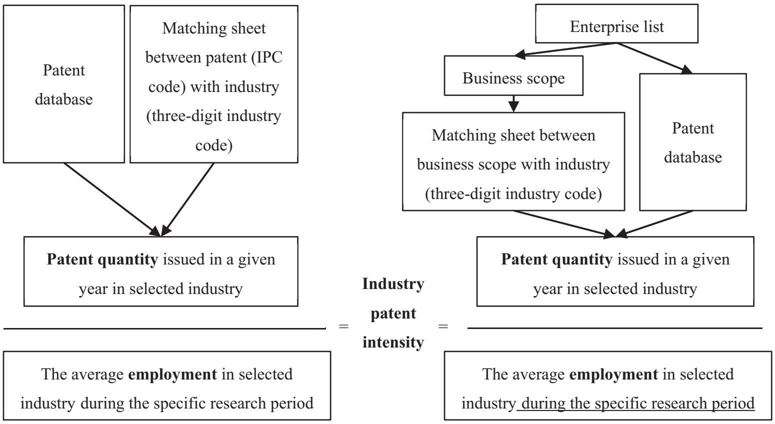
The 2012 US report first identified 75 industries that rely most heavily on patents as patent-intensive industries (U.S. Department of Commerce, 2012). This generated considerable interest and energized other countries and regions to produce similar studies investigating the contribution of patents to their countries and regional economies. Meanwhile, the 2013 EU report defined patent-intensive industries as those having an above-average use of patents per employee (Office for Harmonization in the Internal Market and the European Patent Office, 2013).

According to the above definition, patent intensity (which is patent quantity per capita in the selected industry) should be larger than the mean of all the industries, that is,

$$\lambda_i = \frac{P_i}{E_i} > \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} E_i} = \overline{\lambda} \tag{1}$$

λ_i is the patent intensity of industry i, P_i is the total valid/yearly added patent quantity in a given year in industry i, E_i is the average employment in industry i during the specific research period and $\overline{\lambda}$ is the mean of the patent intensity of all the industries.

For the patent intensity of the selected industry, there are two different counting measure methods (Figure 1). The first one is from the industrial perspective. Patents are classified



Notes: 1. Industrial perspective; 2. Enterprise perspective

Figure 1.
Two counting measure methods for industry patent intensity

into specific technology classes that distinguish their inventive content. Additionally, the state patent office (e.g. US Patent and Trademark Office, EPO or CNIPA) often maintains a general concordance system between its technology classifications and industry classification system, which allows researchers to match patents with industry codes. Through this matching, it is practicable to calculate P_i in equation (1). Another measuring method is from the enterprise perspective. By using the enterprise list, it is easy to calculate enterprises' owned patents and employees. Meanwhile, each enterprise has declared its business scope before its establishment. Therefore, it is easy to count enterprises' patents in a specific industry.

Compared with these two counting measures, the data collected from the industrial perspective could be more accurate than that from the enterprise perspective, because it does not need to match business scope with industry classification. However, the measure from the industrial perspective does not allow us to find out what the real structure of a patent application is on a microlevel. Specifically, when the "supportive policy" is adopted, more detailed information about an enterprise is needed. Therefore, the selection of counting measure methods should consider governance strategies.

2.2 Classification of patent-intensive industries in China

In 2016, the Chinese report estimated economic contributions of eight China's patent-intensive industries based on data from 2010 to 2014. To provide results that are comparable to those obtained for the US economy and EU economy, CNIPA gives a similar definition that a patent-intensive industry should have an above-average use of patents per employee and must be Chinese strategic industries. The data collection methodology used by CNIPA is very similar to that used in the US/EU reports.

In this study, we used the list of patent-intensive industries from the 2016 Chinese report. As shown in Table 1, this list consists of 42 three-digit industry codes.

The list of China's patent-intensive industries in Table 1 is dominated by manufacturing activities, accounting for 42 of the top 48 industries, except the software and information technology. Note that in this study we only paid attention to manufacturing industries.

Industry classification	Industry code	Industry name	Patent intensity[①]
Information equipment manufacturing sector	391	Computer manufacturing	88.58
	392	Telecommunication manufacturing	322.22
	393	Manufacturing of broadcast television equipment	333.32
	394	Manufacturing of radar and its supporting equipment	789.95
	396	Electronic device manufacturing	92.47
Software and information technology sector	651	Software development	58.87
	652	Information system integration service	
	653	Information technology consulting service	
	654	Data management and storage service	
	655	Integrated circuit design	
	659	Other information technology services	
Transportation equipment sector	361	Automobile manufacturing	6.70
	366	Automotive components manufacturing	20.06
	371	Railway transport equipment manufacturing	47.01
	374	Aviation and spacecraft equipment manufacturing	34.71
Intelligent manufacturing equipment sector	342	Metal machinery manufacturing	279.50
	343	Material handling equipment manufacturing	120.87
	351	Mining, metallurgy and building equipment manufacturing	97.63
	354	Printing and pharmaceutical equipment manufacturing	295.55
	355	Textile, clothing and leather equipment manufacturing	151.38
	356	Electronic and electrical equipment manufacturing	171.18
	357	Agriculture, forestry and equipment manufacturing	179.51
Biopharmaceutical sector	271	Chemical raw materials manufacturing	151.02
	272	Chemical agents manufacturing	111.46
	273	Chinese herbal pieces manufacturing	799.80
	274	Chinese patent medicine manufacturing	203.73
	276	Biopharmaceutical manufacturing	832.93
	358	Medical instruments and equipment manufacturing	479.18
	404	Optical instruments and glasses manufacturing	125.91
New functional materials sector	261	Basic chemical raw materials manufacturing	208.26
	263	Pesticide manufacturing	229.54
	264	Paint, ink and related materials manufacturing	151.07
	265	Synthetic material manufacturing	159.69
	266	Special chemical products manufacturing	293.85
	268	Daily chemical products manufacturing	137.51
Energy-saving and environmental protection sector	341	Boiler and power equipment manufacturing	141.93
	344	Pump, valve and compressor manufacturing	77.14
	346	Oven, fan and weighing equipment manufacturing	268.14
	352	Chemical and wood processing equipment manufacturing	208.89
	359	Environmental protection equipment manufacturing	435.56
	382	Power distribution and control equipment manufacturing	127.45
	384	Battery manufacturing	92.93
	387	Lighting equipment manufacturing	81.72
	401	General instrument manufacturing	735.87
	402	Special instrument manufacturing	910.73
Resource recycling-based sector	336	Metal surface treatment and heat treatment processing	230.82
	462	Sewage treatment and recycling	1,313.40
	469	Other water treatment, utilization and distribution	1,568.14

Note: [①]The unit of patent intensity is the patent quantity per 10,000 people employed in the selected industry

Table 1. List of China's patent-intensive industries

3. Data and research methods

3.1 Data collection

This study collected data from the industrial perspective as shown in Figure 1. First, using the list of China's patent-intensive industries shown in Table 1, we matched the three-digit industry code with International Patent Classification (IPC) codes. An example is shown in Table 2.

Second, we searched for the matched IPC codes in the Innography Database provided by Thomson Reuters and counted the patent quantity in a given year in the selected three-digit industry codes. In this way, this study collected patent quantity information by the above-mentioned three-digit industry code from 2012 to 2015. Meanwhile, for average employment, data was collected from the National Bureau of Statistics of the PRC. Then, the industry patent intensity could be calculated directly. Last, economic data was gathered from the China Industrial Economic Statistical Yearbook for the period from 2012 to 2015.

It is noted that CNIPA published the list of China's patent-intensive industries based on the data for the period from 2010 to 2014. However, the China Industrial Economic Statistical Yearbook did not provide economic data from three-digit industries until 2012. In addition, the three-digit industry code has been revised in 2017 which cannot be easily matched to the intensive industries in the 2016 report. That is why our research chose the period from 2012 to 2015.

3.2 Research methods

To find the relationship between patents and economic growth, previous research has focused on two directions (Falvey *et al.*, 2006; Chu and Peng, 2011). Direction 1 pays attention to the relationship between the patent protection system and economic growth. The panel data and regression model are normally used. On the other hand, Direction 2

391	Computer manufacturing	Matched 391 with IPC code
3911	Computer machine manufacturing	G06F15/00*, G06F15*, G06F15/02*, G06F15/04*, G06F15/08*, G06F15/10*, G06F15/12*, G06F15/14*, G06F15/16, G06F15/163*, G06F15/167*, G06F15/17*, G06F15/173*, G06F15/177*, G06F15/18*, G06F15/76*, G06F15/78*, G06F15/80*, G06F15/82*
3912	Computer parts manufacturing	G06C5*, G06C7*, G06C9*, G06C17*, G06C19*, G06C21*, G06C23*, G06C25*, G06F1*, G06F3, G06F13*, G11B7/2407*, H04W, H05K5, H05K7, H05K9, H05K10, H05K13
3913	Computer accessories manufacturing	B41J, G03G, G06C11*, G06C13*, G06C15*, G06F3, G11B3/00, G11B3/64*, G11B5/00, G11B5/62*, G11B5/627*, G11B5/633*, etc. G11B7/00, G11B7/24*, G11B7/24003*, G11B7/24006*, etc., G11C, H04N1
3919	Other related equipment manufacturing	G06C27*, G06C29*, G06D*, G06E*, G06F11*, G06F21*, G06G3, G06G5*, G06G7*, G06J*, G06N*, G09B9, G09C*, H04B17, H04K, H04L1, H04L7, H04L9, H04L12, H04L13, H04L29

Table 2. Matching sheet between three-digit industry codes and IPC codes (391 as an example)

focuses on patent transfers across borders through three independent channels: international trade, FDI and the contractual licensing of technologies to unaffiliated firms. Panel data and regression models are used frequently (Park and Ginarte, 1997).

The classic Cobb-Douglas function introduces technology factors to study the input-output relationship, which is used to analyze and predict the way of national production development. To investigate the relationship between patent intensity and economic development, we used the classic Cobb–Douglas function to present the contribution of labor, capital and patents to economic development:

$$Y = L^{\beta_1} K^{\beta_2} T^{\beta_3} \mu \tag{2}$$

Divide L and take the log of both sides of equation (2), and then we have:

$$\mathrm{Ln}\left(\frac{Y}{L}\right) = \beta_1 + \beta_2 \mathrm{Ln}\left(\frac{K}{L}\right) + \beta_3 \mathrm{Ln}\left(\frac{T}{L}\right) + \mu \tag{3}$$

In equation (3), variable $\frac{Y}{L}$ is the economic indicators per capita, variable $\frac{K}{L}$ is the fixed-asset investments per capita, variable $\frac{T}{L}$ is the patent intensity and μ is the stochastic error term.

Similar to these two directions, a panel data and regression model were used in this study. The panel data were for the period from 2012 to 2015. All variables are described below.

3.2.1 Dependent variables. Previous research regarded GDP, enterprise competitive advantage and international trade as economic indicators. Therefore, this study used gross industrial output value (GIOV), MBR and ER as dependent variables for each specific industry (level of three-digit industry code). These three variables provide a more comprehensive understanding of the economic contributions made by patent-intensive industries.

3.2.2 Independent variables. To represent the degree of patent protection, many previous studies have used the number of patent applications/granted quantity (Maskus, 2000), patent litigation (Ldris, 2003), patent development activities and the patent index (Chu and Peng, 2011) as manifest variables. These variables are absolute values, but do not consider differences in industry size. To avoid this limitation, this study first attempted to use patent intensity as an independent variable.

In this study, we considered two types of patent intensity. Type 1 is the intensity of valid patents in a selected three-digit industry in a selected year, which is a proxy of the stock of patent intensity. Type 2 is the intensity of yearly added patents in a selected three-digit industry in a selected year, which is a proxy of the incremental patent intensity. For Type 2, the yearly added patents are equal to the number of granted patents minus the number of invalid patents in a selected year.

In addition, fixed-asset investment was also regarded as an independent variable in this study. To check the input–output efficiency from the patent intensity perspective, R&D institutes, R&D staff and R&D intensity of the three-digit industries were considered. Table 3 shows the descriptive statistics for all variables.

4. Research results

4.1 Economic contribution of patent-intensive industries

First, from the perspective of GIOV, only automobile manufacturing (361), basic chemical raw materials manufacturing (261), synthetic material manufacturing (265), special chemical products manufacturing (266) and other water treatment, utilization and distribution (469) had remarkable economic performance. By contrast, most of the three-digit industries, for example, optical instruments and glasses manufacturing (404), had a smaller value of GIOV than the mean. Compared with the whole industry (672 industry codes in total), only 14/17

(Type 1/Type 2 of patent intensity) three-digit industries had a GIOV larger than the mean. The situation looks much better if we use the median as a dividing point. There are 25/27 (Type 1/Type 2 of patent intensity) three-digit industry codes that had GIOVs larger than the median.

Figure 2 shows a large gap in GIOV among China's patent-intensive industries. More importantly, it seems that the positive correlation between patent intensity and GIOV value is weak in many three-digit industries because they do not converge near each other.

For this phenomenon, we propose two reasons. The first reason is that, to some extent, China's traditional patent incentive policies have been excessive, pursuing quantity growth rather than quality improvement, leading to China's patent-intensive industry being bloated. The second reason is that some industries are not driven by innovation (which is mainly invention patents). Their well glaring economic performance benefits from China's development trend.

From the perspective of MBR, Figure 3 shows that automobile manufacturing (361), basic chemical raw materials manufacturing (261), synthetic material manufacturing (265), special chemical products manufacturing (266) and other water treatment, utilization and distribution (469) had highlighted performance. By contrast, the industry of manufacturing radar and its supporting equipment (394) had higher patent intensity (ranked sixth in Figure 3), but its MBR was smaller than the mean. On the one hand, this phenomenon is similar to that

Table 3.
Descriptive statistics for all dependent/independent variables

Variable	No. of observations	Mean	SD	Minimum	Maximum
GIOV per capita	168	100.44	45.98	20.92	270.50
MBR per capita	168	108.14	100.90	21.16	1,261.97
ER per capita	168	14.94	20.03	0	98.09
Type 1 of patent intensity	168	1,680.61	5,192.91	9.37	4,701.67
Type 2 of patent intensity	168	272.41	1,099.73	−337.16	1,214.44
Fixed-asset investment per capita	168	28.80	28.96	4.81	228.13
*R&D institute**	42	352.80	347.76	0	2,058
*R&D staff**	42	17,835.28	22,018.27	0	5053167.00
*R&D intensity**	42	0.02	0.02	0	0.094

Note: *For the R&D situations of the three-digit industries, there is no continuous statistics data. The latest data came from the Chinese Economic Census Yearbook (2013)

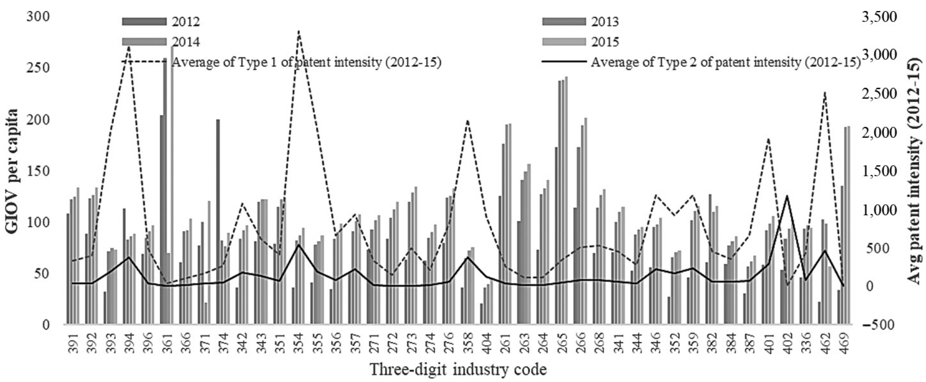


Figure 2.
Gross industrial output value per capita by three-digit industry code

presented in Figure 2; the MBR varies among different three-digit industries. On the other hand, it indicates that China has not developed a strongly positive relationship between patent intensity and MBR.

In comparing Figure 2 with Figure 3, it is obvious that GIOV and MBR have similar fluctuations, although the value of MBR is smaller than that of GIOV.

From the perspective of ER, Figure 4 shows that computer manufacturing (391), telecommunication manufacturing (392), electronic device manufacturing (396) and other water treatment, utilization and distribution (469) had impressive ER value compared with other three-digit industries. This indicates that the ER of China's patent-intensive industries is pushed by a few star industries. For the most part, China's patent-intensive industries are not export-oriented but mainly rely on the domestic market. These industries do not have the ability to participate in global competitiveness. In terms of means, the group of patent-intensive industries (42 three-digit industry codes) had a higher ER value than the mean of all industries (672 three-digit industry codes).

In comparing the three figures, Figure 4 presents a different economic view from Figures 2 and 3. For example, automobile manufacturing (361) had prominent GIOV and MBR performance, but its ER value was very small. In addition, Figure 4 shows the largest value gap between patent intensity and economic performance.

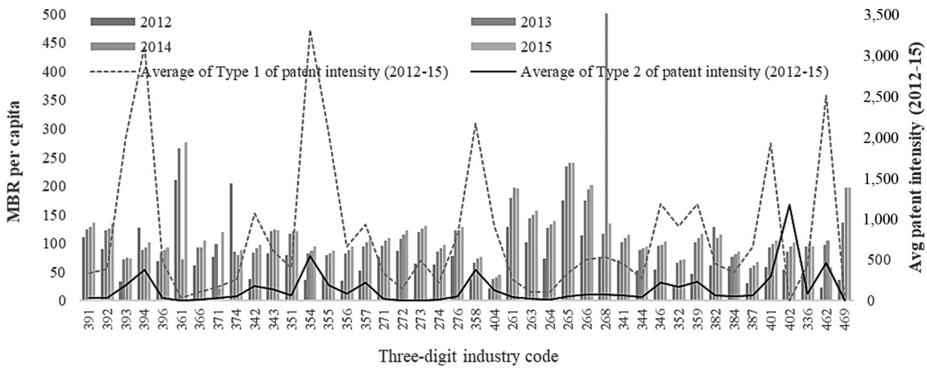


Figure 3.
Main business revenue per capita by three-digit industry code

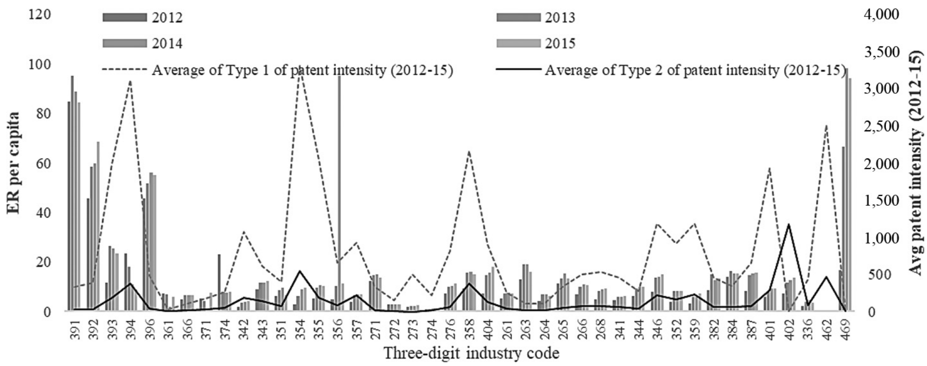


Figure 4.
Export revenue per capita by three-digit industry code

4.2 Relationship between patent intensity and economic development

As shown in Table 4, Type 1 of patent intensity has a positive impact on the three economic indicators, especially GIOV and MBR. In addition, all of the three economic indicators are strongly influenced by the variable of fixed-asset investment per capita presenting the significance level of 1%. So Table 4 demonstrates that the increasing number of valid patents is beneficial to the development of the industry. This result is in line with previous traditional research.

However, for Type 2 of patent intensity, Table 5 shows its insignificant relationship with the three economic indicators. The correlations to GIOV and ER are even negative, but with little significance. Thus, considering the influence of yearly added patents, Table 5 presents a different result from Table 4 that needs to be validated further. In addition, for fixed-asset investment per capita, it presents significant promotion to industry development, at the significance level of 1%.

To validate the results shown in Table 5, we first compare the economic indicators with Type 2 of patent intensity and then found that some three-digit industries with better economic performance have a low intensity of yearly added patents (i.e. 361), whereas some industries have good performance in economic growth and yearly added patent intensity (i.e. 354). It is hard to infer whether there is a strictly linear relationship between them. Therefore, this paper attempted to investigate the real influence of Type 2 of patent intensity on economic performance by dividing the 42 three-digit industries into two groups.

First, we standardized all data through an equalization method to eliminate dimensions so that the data had the same caliber. Then, we proposed an absolute distance to reveal the gap between the economic indicator and Type 2 of patent intensity based on square processing. As shown in Table 6, in Group 1, all three-digit industries have a smaller absolute distance than the distance median. In Group 2, their absolute distance is larger than the distance median. By using this method, the industries where Type 2 of patent intensity converges near the economic indicators can be screened out.

As shown in Table 6, the 42 three-digit industries were divided into two groups. In Group 1, the patent intensity converged near the industry's economic indicators. This shows that these industries had reasonable patent intensities which were suited to their economic performance.

Table 4. Relationship between economic indicators and Type 1 of patent intensity

Independent variables \ Dependent variables	GIOV	MBR	ER
Type 1 of patent intensity	0.1497***(0.0369)	0.4121***(0.0950)	0.0206(0.0409)
Fixed-asset investments per capita	0.7167***(0.0444)	0.3257***(0.1091)	0.7363***(0.0582)
R^2	0.9081	0.5693	0.7173

Notes: *Significant at 10%, **significant at 5%, ***significant at 1%

Table 5. Relationship between economic indicators and Type 2 of patent intensity

Independent variables \ Dependent variables	GIOV	MBR	ER
Type 2 of patent intensity	−0.0025(0.0149)	0.0127(0.0310)	−0.0356(0.0224)
Fixed-assets investment per capita	0.8099***(0.0377)	0.6760***(0.0805)	0.7253***(0.0551)
R^2	0.8744	0.4909	0.6897

Notes: *Significant at 10%, **significant at 5%, ***significant at 1%

Groups	GIOV	MBR	ER
Group 1 (distance < median)	• 391, 392, 396 • 366, 371, 374 • 343, 351, 356 • 271, 274, 276 • 266, 268 • 341, 344, 352, 382, 384, 387 • 336	• 391, 392, 396 • 366, 371, 374 • 343, 351, 356 • 271, 274, 276 • 264, 266 • 341, 344, 352, 382, 384, 387 • 336	• 391, 392 • 361, 366, 371, 374 • 341, 344, 382, 384 • 271, 272, 273, 274, 276 • 261, 263, 264, 265, 266 • 351
Group 2 (distance ≥ median)	• 393, 394 • 361 • 342, 354, 355, 357 • 272, 273, 358, 404 • 261, 263, 264, 265 • 346, 359, 401, 402 • 462, 469	• 393, 394 • 361 • 342, 354, 355, 357 • 272, 273, 358, 404 • 261, 263, 265, 268 • 346, 359, 401, 402 • 462, 469	• 393, 394, 396 • 342, 343, 354, 355, 356, 357 • 358, 404 • 268 • 346, 352, 359, 387, 401, 402 • 336, 462, 469

Table 6.
Two groups divided by the distance gap

In Group 2, there is a larger distance gap between the economic indicators and patent intensity. We hypothesize that there are two scenarios. One is high economic growth with lower patent intensity, such as automobile manufacturing industry (361, 6.7). That is because some of these industries are natural monopolies and some of them are driven by market rather than patents. The other scenario is high patent intensity with poor economic performance, such as manufacturing of radar and its supporting equipment industry (394, 789.95), as a result of some naturally technology-intensive industries share small markets, such as radar manufacturing. More importantly, we have to admit that most industries in this scenario had patent bloat.

Because the correlation between economic indicators and Type 2 of patent intensity shown in Table 5 is not significant by using the linear model, we attempted to use a nonlinear model to regress the panel data from 2012 to 2015. The equation is as below:

$$\mathrm{Ln}\left(\frac{Y}{L}\right) = \beta_1 + \beta_2 \mathrm{Ln}\left(\frac{K}{L}\right) + \beta_3 \mathrm{Ln}\left(\frac{T}{L}\right) + \beta_4 \left(\mathrm{Ln}\left(\frac{T}{L}\right)\right)^2 + \mu \tag{4}$$

For the three-digit industries in Group 1, Table 7 shows that the economic indicators (i.e. GIOV, MBR and ER) and Type 2 of patent intensity represent an inverse U-shaped curve. Specifically, Type 2 of patent intensity has a positive relationship with GIOV, MBR and ER at the significance level of 10%, 5% and 1%, respectively. Meanwhile, the square of Type 2 of patent intensity is negative with these economic indicators at a less significant level. These results demonstrate that there is a "saturation point" for patent-intensive industries in Group 1.

The Type 2 of patent intensity represents the yearly patent growth per capita. Once the Type 2 of patent intensity exceeds this saturation point, the economic return contributed by patent growth decrease. However, if policymakers adopt policies that promote high-quality patent growth, they can shift the top of the inverse U-shaped curve to the right, delaying the dampening effect of patent growth on the economy.

In comparing the saturation point in models 1, 2 and 3, the economic indicators (i.e. GIOV, MBR and ER) have different requirements for patent growth. ER has the lowest saturation value (inflection point = 3.35), indicating that increasing the ER value does not need high patent yearly growth. This has been tested by China's experience. During the past 30 years, China has been the world's largest exporter, even though the export products have few patents.

Last, Table 7 indicates that the fixed-asset investment plays a more significant role in economic development.

For the three-digit industries in Group 2, Table 8 shows that the three economic indicators (i.e. GIOV, MBR and ER) and the Type 2 of patent intensity form a U-shaped curve. Specifically, the Type 2 of patent intensity has a negative relationship with the economic indicators at the significance level of 1% or 10%, whereas its square has a positive relationship with the economic indicators. These results indicate that there is a "threshold effect" for patent-intensive industries in Group 2. The Type 2 of patent intensity represents the yearly patent growth per capita. When patent growth is not large enough, its economic return cannot cover costs. In this scenario, increasing Type 2 of patent intensity is not beneficial to economic development. Only when the Type 2 of patent intensity is over the value of the threshold can it effectively promotes economic development.

Moreover, if high-quality patents account for a higher proportion of all year added patents, the lowest point of the U-shape curve may shift to the left because in the case of paying attention to patent quality, a small number of high-quality patents added in a year may lead to economic development across the threshold rapidly and realize the positive promotion effect of patent growth on the economy.

In addition, effectiveness is more significant when considering the impact of fixed-asset investment per capita, which is similar to that of Table 7.

5. Discussion

5.1 Patent lack versus patent saturation

Compared with the three-digit patent-intensive industries in the USA and EU, Table 1 shows that China's patent intensity is still at a considerably low level on the whole. For example, China's patent intensity in computer manufacturing is only 10% of that of the USA. It seems that the phenomenon of patent lack in China is obvious.

On the other hand, there are three exceptions: 271, 276 and 402. Their patent intensities are larger than that of the USA and EU. To investigate this phenomenon, we interviewed the vice director of the department of patent protection and coordination in CNIPA. The vice director admitted that some three-digit industries with such higher patent intensity could be regarded as having patent saturation. For example, it is a common sense that China's drug industry (271 and 276) is dominated by generic drugs. There are many generic drug patents, but very few original drug patents. Therefore, it is not a surprise that the patent intensity of 271 in China is larger than that in the USA. In addition, when considering the relationship between patent intensity and economic development, Table 8 also indicates that there are saturation points for selected patent-intensive industries in Group 2.

Considering that some industries may have patent saturation, CNIPA changed the patent evaluation index in the "Guidelines for Building a Powerful Country with Intellectual Property Rights (2021-2035)" to reduce patent saturation. The previous evaluation index was the number of invention patents per 10,000 population. Now CNIPA uses the number of high-value invention patents per 10,000 population as new patent evaluation index and

Table 7.
Relationship between economic indicators and Type 2 of patent intensity in Group 1

Variables	Model 1 GIOV		Model 2 MBR		Model 3 ER	
Type 2 of patent intensity	0.0961*(0.0563)	0.32**(0.1563)	0.0963**(0.0564)	0.31**(0.1566)	0.3257***(0.0865)	0.48*** (0.1492)
Square of Type 2 of patent intensity	−0.0125(0.0090)	−0.04*(0.0246)	−0.0123(0.0091)	−0.04*(0.0248)	−0.0486***(0.0148)	−0.07*** (0.0257)
Fixed-asset investment per capita	0.8413***(0.0422)		0.8309***(0.0420)		0.666***(0.0685)	
R^2	0.4365	0.1036	0.4380	0.0938	0.4822	0.2259
Observations	84		84		84	
Shape			Inverse U-shaped curve			
Inflection point	3.84		3.91		3.35	

Notes: *Significant at 10%, **significant at 5%, ***significant at 1%

Table 8.
Relationship between economic indicators and Type 2 of patent intensity in Group 2

Variables	GIOV		MBR		ER	
Type 2 of patent intensity	−0.1417(0.0906)	−0.59***(0.1469)	−0.2469(0.1535)	−0.65*** (0.1768)	−0.6053*(0.3465)	−1.07*** (0.3637)
Square of Type 2 of patent intensity	0.0129(0.0092)	0.06***(0.0148)	0.0183(0.0156)	0.06*** (0.0177)	0.0530*(0.0324)	0.10*** (0.0331)
Fixed-asset investment per capita	0.7536***(0.0634)		0.6309***(0.0952)		0.5930***(0.1470)	
R^2	0.4408	0.2155	0.4129	0.2001	0.4417	0.1491
Observations	84		84		84	
Shape			U-shaped curve			
Inflection point	5.49		6.75		5.71	

Notes: *Significant at 10%, **significant at 5%, ***significant at 1%

defined five types of high-value invention patents, including invention patents in strategic emerging industries, invention patents that have the patent families overseas, invention patents with a validity span of more than 10 years, invention patents with higher number pledge financing and invention patents that have won the National Science and Technology Award or Chinese Patent Award. According to the guidance of high-value patent oriented policy, patent applicants, especially enterprises, would apply for invention patents that meet the conditions of high-value invention patents and reduce the application behavior for low-value patents, so as to reduce the patent saturation.

On the other hand, CNIPA should reduce patent saturation by adjusting industrial policies. Although patent promotion policies that aim to increase the Type 1 of patent intensity are needed (see Table 4), industrial differences should be given more attention by Chinese policymakers. For some three-digit industries with probability patent saturation, patent incentive policies should be abolished or avoided as soon as possible.

5.2 Which governance strategy should be adopted in China?

As shown in Table 6, China's patent-intensive industries are divided into two groups. In Group 1, Type 2 of patent intensity and economic indicators present an inverse U-shaped curve, whereas the other three-digit industries in Group 2 present a U-shaped curve. From the policy perspective, we believe enhancement policies should be adopted to encourage industries with poor economic performance but with high patent intensity to help them continue their inventions and patenting activities and catch up to their competitors in the US or EU in the future. For Group 2, supportive policies should be adopted for Group 1 to increase the patent intensity of selected industries in order to help them over the threshold.

Much previous research has pointed out that patent production mainly depends on R&D input, including enterprise R&D organizations, enterprise R&D staff and R&D intensity. Using the panel data from 2013, this study investigated input–output efficiency regarding patent intensity as the output. Table 9 shows that the values of Crste in the two groups are at low levels, except for 394 and 462. This indicates that the input–output efficiency of Group 1 and Group 2 are not satisfied. In addition, China's enterprises emphasize R&D scale rather than R&D quality; in other words, technical efficiency is short than scale efficiency because the values of Vrste are smaller than that of scale in Table 9.

Comparing actual input with target input, Table 9 shows that R&D resources in many three-digit industries are overinvested. Specifically, R&D institutions are the most heavily overinvested resources, followed by R&D intensity and R&D staff. To improve input–output efficiency, supportive and enhancement policies should focus on improving an enterprise's R&D quality, rather than R&D quantity.

5.3 Patent-intensive industry perspective versus traditional patent scheme perspective

There is no doubt that the patent system is a major part of the economic system in every country. The patent system promotes technological and business competition because patent holders must disclose invention details in exchange for the specified period during which they have exclusive rights over their exploitation (Ldris, 2003; Panagopoulos, 2009). Based on this understanding, traditional research about patent legal system mainly discussed the relationship between patent rights protection and economic growth from the perspective of a cross-section of countries during a selected period. These studies aimed to find an optimal balance between patent rights owners and social welfare and between multinational companies and domestic interest in a specific circumstance.

However, focusing on patent protection cannot create a win–win situation because some compromises must be made (Grossmann and Steger, 2008). When studies put more

Table 9.
Input–output efficiency of patent intensity from 2013

Industry code		Type 2 of patent intensity	Actual input R&D institutes	Actual input R&D staff	Actual input R&D intensity	Target input R&D institutes	Target input R&D staff	Target input R&D intensity	Crste	Vrste	Scale	
G1	391	122.06	342	241.89	0.64	24.61	130.38	0.64	0.381	0.462	0.824	irs
	392	155.42	481	760.31	2.96	312.00	760.31	2.24	0.119	0.165	0.722	drs
	396	132.57	884	336.41	1.61	249.82	336.41	1.61	0.198	0.259	0.766	drs
	366	4.42	1933	234.21	0.97	102.28	234.21	0.97	0.011	0.012	0.910	drs
	371	9.70	197	515.18	2.31	197.00	515.18	2.00	0.010	0.014	0.706	drs
	374	255.71	139	3166.17	6.88	40.00	2311.14	4.13	0.068	0.104	0.655	drs
	343	18.15	545	439.88	1.33	121.18	439.88	1.33	0.029	0.031	0.928	drs
	351	49.10	1054	384.09	1.67	275.39	384.09	1.67	0.069	0.087	0.789	drs
	356	420.06	217	240.29	1.67	217.00	240.29	1.67	0.654	1.000	0.654	drs
	271	134.45	558	559.54	1.92	310.29	559.54	1.92	0.153	0.182	0.843	drs
	274	74.87	592	423.87	1.44	187.32	423.87	1.44	0.113	0.128	0.882	drs
	276	319.56	396	583.20	2.23	343.06	583.21	2.02	0.324	0.415	0.780	drs
	266	135.95	1306	307.28	0.87	25.65	277.71	0.87	0.318	0.330	0.965	irs
	268	194.11	236	169.73	0.71	31.58	169.73	0.72	0.630	0.637	0.989	drs
	341	23.80	460	432.27	1.90	313.39	432.27	1.86	0.029	0.039	0.765	drs
	344	10.54	1114	273.63	1.31	195.33	273.63	1.31	0.019	0.024	0.805	drs
	352	141.35	731	190.80	1.33	163.99	190.80	1.33	0.277	0.396	0.699	drs
	382	41.47	2058	370.35	1.45	232.18	370.35	1.45	0.065	0.077	0.843	drs
	384	37.36	350	304.37	1.36	212.57	304.37	1.36	0.065	0.079	0.818	drs
	387	46.67	523	168.88	1.22	144.24	168.88	1.22	0.100	0.141	0.711	drs
	336	26.52	159	69.51	0.53	24.13	63.06	0.53	0.133	0.135	0.984	irs
AVG		287.50	424.76	431.00	1.55	160.91	437.53	1.51	0.29	0.34	0.82	
G2	393	268.87	202	389.26	1.83	202.00	389.26	1.83	0.351	0.476	0.739	drs
	394	2450.44	40	2311.14	4.13	40.00	2311.14	4.13	1.000	1.000	1.000	–
	361	2.89	271	769.77	1.33	27.68	565.01	1.33	0.004	0.004	0.884	–
	342	63.93	820	245.57	1.40	193.15	245.58	1.40	0.114	0.154	0.739	drs
	354	341.25	204	230.05	1.33	179.73	230.05	1.33	0.644	0.862	0.747	drs
	355	32.25	324	300.82	1.55	229.44	300.82	1.55	0.051	0.068	0.751	drs
	357	27.14	238	210.51	1.08	147.93	210.51	1.08	0.061	0.074	0.827	drs
	272	58.56	569	614.80	2.11	337.52	614.80	2.06	0.061	0.073	0.828	drs
	273	137.36	132	200.33	0.69	24.83	162.01	0.69	0.436	0.464	0.939	irs

(*continued*)

Industry code	Type 2 of patent intensity	Actual input R&D institutes	R&D staff	R&D intensity	Target input R&D institutes	R&D staff	R&D intensity	Crste	Vrste	Scale	
358	102.70	379	329.91	2.65	261.99	329.91	1.76	0.104	0.200	0.517	drs
404	126.39	146	199.70	2.43	146.00	199.70	1.29	0.158	0.349	0.452	drs
261	77.19	1090	252.40	0.78	25.22	216.50	0.78	0.209	0.220	0.951	irs
263	38.10	320	522.09	1.39	85.24	522.09	1.39	0.055	0.057	0.959	drs
264	27.97	670	293.23	1.06	103.79	293.23	1.06	0.058	0.064	0.920	drs
265	147.67	705	350.30	0.99	26.77	350.30	0.99	0.304	0.305	0.999	–
346	78.35	754	318.49	1.53	234.65	318.49	1.53	0.123	0.159	0.774	drs
359	99.60	742	327.89	1.48	233.84	327.89	1.48	0.159	0.200	0.799	drs
401	114.79	931	603.89	2.05	339.44	603.89	2.05	0.122	0.145	0.838	drs
402	703.45	355	515.14	1.94	355.00	515.14	1.94	0.815	1.000	0.815	drs
462	178.00	24	44.36	0.50	24.00	44.36	0.50	1.000	1.000	1.000	–
469	960.52	4	21.41	0.25	/	/	/	/	/	/	/
AVG	112.09	679.76	484.37	1.73	177.29	436.63	1.54	0.18	0.22	0.81	

Table 9.

emphasis on patent protection, they may ignore the real influence of patents on industries and their contribution to the economy. That is why previous studies have provided so many fragmented and somewhat contradictory findings.

The investigation of patent-intensive industries could be regarded as another way to evaluate the economic contribution of patents in a definite manner. The US/EU reports and our research all pointed out that patent-intensive industries (rather than patents) were becoming a major part of the international economy. Indeed, patent quantity had a significant positive impact on country and regional economies from an industrial perspective. Given this understanding, central and local governments should focus on industrial policies to foster patent-intensive industries, rather than adopt strong/weak patent protection in the legal system. Therefore, we are convinced that our research on patent-intensive industries is a valuable addition, will enrich traditional patent studies and could be regarded as a necessary part of patent economy theory.

6. Conclusion

Patent protection and the patent economy are two different and indivisible problems. Based on the list of patent-intensive industries from CNIPA, this study investigated these industries' economic contributions through descriptive statistics and the relationship between patent intensity and economic indicators through panel data. We also checked the input–output efficiency of China's patent-intensive industries.

The main contribution of this research was exploring the relationship between patent intensity and economic development based on China's patent-intensive industries from an empirical perspective. First, although these industries accounted for over one-tenth of China's economy, there were significant gaps among different industries from the perspective of GIOV, MBR and ER. Second, based on the panel data from 2012 to 2015, we found that the intensity of valid patents was strongly positively related to economic indicators. In terms of the intensity of yearly added patents, there were two relationships with economic indicators, an inverse U-shaped curve and a U-shaped curve, indicating that the 42 patent-intensive industries had to be divided into two groups. Lastly, our results showed that input–output efficiency was not satisfied. R&D institutions were most heavily overinvested, followed by R&D intensity and R&D staff.

Like many studies, this study had limitations. First of all, the data was a common restriction. We used panel data from 2012 to 2015 because the China Industrial Economic Statistical Yearbook did not provide data about three-digit industries until 2013 and revised three-digit industries in 2017. Second, our analysis was based on the economic performance of China's patent-intensive industries. How patents play a role in economic development was not taken into account. Therefore, for further research, a natural extension would be to explore the "dark box" of patent economy. For instance, patent quantity, patent quality, government support, internal and external R&D investment intensity, and international environment are possible factors affecting patent-intensive industries and economic growth. Finally, other interesting issues need to be explored in further research, including the consideration of cost-saving, capital structure and patent propensity of patent-intensive industries. The most interesting but hardest work is to investigate patent protection and the patent-intensive industry in one framework.

References

Awokuse, T.O. and Yin, H. (2010), "Does stronger intellectual property rights protection induce more bilateral trade? Evidence from China's imports", *World Development*, Vol. 38 No. 8, pp. 1094-1104.

Chen, H., Li, M.Q., Li, J.Q. and Chen, W. (2022), “Collaboration and evolution of intellectual property management capabilities in patent-intensive industries”, *Studies in Science of Science*, Vol. 40 No. 4, pp. 652-664.

Chinese Economic Census Yearbook (2013), China Statistics Press, Beijing, available at: www.stats.gov.cn/tjsj/pcsj/jjpc/3jp/indexch.htm.

Chu, A.C. and Peng, S.K. (2011), “International intellectual property rights: effects on growth, welfare and income inequality”, *Journal of Macroeconomics*, Vol. 33 No. 2, pp. 276-287.

Falvey, R., Foster, N. and Greenaway, D. (2006), “Intellectual property rights and economic growth”, *Review of Development Economics*, Vol. 10 No. 4, pp. 700-719.

Grossmann, V. and Steger, T.M. (2008), “Anti-competitive conduct, in-house R&D, and growth”, *European Economic Review*, Vol. 52 No. 6, pp. 987-1008.

Janjua, P.Z. and Samad, G. (2007), “Intellectual property rights and economic growth: the case of middle income developing countries”, *The Pakistan Development Review*, Vol. 46 No. 4II, pp. 711-722.

Jiang, N., Shan, X.G. and Qi, S. (2014), “Contribution to economy of intellectual property intensive industries in China”, *Studies in Science of Science*, Vol. 32 No. 8, pp. 1157-1165.

Khoury, T.A. and Peng, M.W. (2011), “Does institutional reform of intellectual property rights lead to more inbound FDI? Evidence from Latin America and the Caribbean”, *Journal of World Business*, Vol. 46 No. 3, pp. 337-345.

Kim, M., Kim, J., Sawng, Y. and Lim, K. (2018), “Impacts of innovation type SME’s R&D capability on patent and new product development”, *Asia Pacific Journal of Innovation and Entrepreneurship*, Vol. 12 No. 1, pp. 45-61.

Kim, Y.K., Lee, K., Park, W.G. and Choo, K. (2012), “Appropriate intellectual property protection and economic growth in countries at different levels of development”, *Research Policy*, Vol. 41 No. 2, pp. 358-375.

Ldris, K. (2013), *Intellectual Property: A Power Tool for Economic Growth*, World Intellectual property organization, Switzerland, pp. 1-379.

Li, B.Z. and Wang, D. (2020), “Dynamic efficiency and spatial-temporal evolution of patent-intensive industries in China”, *Studies in Science of Science*, Vol. 38 No. 11, pp. 1987-1997.

Li, L.M. and Chen, M.Y. (2017), “Patent-intensive industry, patent system and economic growth”, *China Soft Science*, Vol. 4, pp. 152-168.

Mansfield, E. (1994), *Intellectual Property Protection, Foreign Direct Investment, and Technology Transfer*, World Bank, Washington, DC.

Mansfield, E. (1995), *Intellectual Property Protection, Direct Investment and Technology Transfer: Germany, Japan, and the United States*, World Bank, Washington, DC.

Maskus, K.E. (2000), “Intellectual property rights and economic development”, *Case Western Reserve Journal of International Law*, Vol. 32 No. 3, pp. 471-506.

Maskus, K.E. and McDaniel, C. (1999), “Impacts of the Japanese patent system on productivity growth”, *Japan and the World Economy*, Vol. 11 No. 4, pp. 557-574.

Maskus, K.E. and Penubarti, M. (1995), “How trade-related are intellectual property rights?”, *Journal of International Economics*, Vol. 39 Nos 3/4, pp. 227-248.

Mazzoleni, R. and Nelson, R.R. (1998), “The benefits and costs of strong patent protection: a contribution to the current debate”, *Research Policy*, Vol. 27 No. 3, pp. 273-284.

Office for Harmonization in the Internal Market and the European Patent Office (2013), “Intellectual property rights intensive industries: contribution to economic performance and employment in the European Union”, p. 32.

Panagopoulos, A. (2009), “Revisiting the link between knowledge spillovers and growth: an intellectual property perspective”, *Economics of Innovation and New Technology*, Vol. 18 No. 6, pp. 533-546.

Park, W.G. and Ginarte, J.C. (1997), "Intellectual property rights and economic growth", *Contemporary Economic Policy*, Vol. 15 No. 3, pp. 51-61.

Park, W.G. and Lippoldt, D.C. (2008), "Technology transfer and the economic implications of the strengthening of intellectual property rights in developing countries", OECD Trade Policy Papers No. 62, Vol. 62, doi: 10.1787/244764462745.

Shan, X.G., Xu, X.F., Chang, X.H. and Chen, X. (2018), "Measurement of patent-intensive industry based on three-digit industry code and Its influential factors", *Journal of Tongji University (Natural science)*, Vol. 46 No. 5, pp. 701-708+714.

U.S. Department of Commerce (2012), *Intellectual Property and the U.S. economy: Industries in Focus*, Economics and Statistics Administration and United States Patent and Trademark Office, Washington, p. 76.

Zhang, D. and Li, Y.C. (2019), "Research on patent risk prevention in patent-intensive industries", *Science Technology and Law*, No. 3, pp. 10-17.

Further reading

Economics and Statistics Administration and United States Patent and Trademark Office (2016), "Intellectual property and the U.S. economy: 2016 update", p. 59.

European Patent Office and the European Union Intellectual Property Office (2016), "Intellectual property rights intensive industries and economic performance in the European Union", p. 156.

European Patent Office and the European Union Intellectual Property Office (2019), "IPR-intensive industries and economic performance in the European Union", p. 16.

Toole, A.A., Miller, R.D. and Rada, N. (2022), *Intellectual Property and the U.S. Economy*, 3rd ed., United States Patent and Trademark Office, Virginia, US, p. 26.

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