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Improved Patent Quality of Strategy Choice

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Abstract

In an open economy, an appropriate patent system is capable of improving the quality of patents. The behavior of governments, enterprises, university research organizations, and intermediary agencies as innovation subjects may also affect patent quality. This work verifies consumers' choice under improved patent quality in terms of patent utilization or purchasers. A model is established on the basis of several variables, including residents' income, patented product price, patented product categories, and complaint rate. The influencing factors that may improve patent quality are also analyzed. Findings show that a product with a considerable number of patents tends to exhibit good quality, but the quality improvement of a highly over-priced patented product may be hindered. Innovation subjects should strengthen the protection of intellectual property rights by improving patent quality.

Keywords

Innovation Subjects, Patent Quality, Consumers' Choice, Improvement

1. Perception of Issues

As the number of patent applications and granted patents increased significantly in recent years, the backlog of patent applications has increased, and patent quality has deteriorated. "Junk patents" and "problematic patents" have gradually emerged and hindered the intensification of technical innovation strategies. At present, the capacity to commercialize technologies is low, core patents are few, surrounding patents are abundant, single patents are dominant, a patent pool is absent, and the promotion of the regional economy through patents is weak. These issues confront China today. Patent quality has drawn increasing concern from countries around the world. The United States, Japan, and the EU have released systems or measures successively to improve patent quality and accelerate the implementation of quality improvement strategies. China has also introduced a patent examination and evaluation system and has employed numerous measures to improve patent quality. In its attempt to raise the review standard and avoid improper patent applications, China has implemented the National Program for Intellectual Property. The knowledge-based economy has clearly grown in a rapid pace. In this case, enterprises should consider improving patent quality and patent use if they aim to secure favorable positions in the industry (Hu, 2007).

Chinese scholars have explored the status quo of China's patent quality and have proposed solutions on the basis of their findings. Wan Xiaoli et al. (Wang & Zhu 2008) analyzed the maintenance time of granted patents and found that the quality of granted patents, especially that of domestic patents, is extremely low in terms of patent maintenance time. Their findings were supported and further developed by XXX et al. Ma Zhong (Ma, 2010) insisted that as an issue decided by the market, patent applications should be decided only after the essential connotation of patents, as well as its system and mission, has been analyzed. Yuan Xiaodong et al. (Yuan & Liu, 2011) analyzed patent quality issues and their root causes and stated that patent quality issues mean that the existence of many problematic patents results in the uncertain validity of a significant number of patents and other related problems.

The foreign scholar Tom Nicholas (Nicholas, 2011) explored the reform of patent policies based on British data and found that such reform, which involves increasing and improving the tendency to file patents by cutting down the filing fee by 84%, has increased the demand for cheap patents. Schankerman M. Pakes (Schankerman & Pakes, 1986) used patent maintenance rate to explore patent quality and assessed the patent quality distribution in three countries (i.e., Britain, France, and Germany). Thomas (Thomas, 2002) explored patent quality from two dimensions, namely, technological quality and economic quality, which are generated from invention creation to the birth of patents, as well as the legal quality derived from patent reliability that functions as an enforceable right.

Some scholars have tried to improve patent quality by exploring the patent index system. Mark Hirscey and Vernon J. Richardson (Hirschey & Richardson, 2004) used scientific value to measure patent quality and their indexes (i.e., citation index, non-patent literature, and technological life cycle). MIT Tech Review measured patent quality using the indexes comprehensive technology strength, patent quantity, current impact index, scientific connection, and technology life cycle. The American OCEAN TOMO established an index system composed of 50 factors, including the quantity of valid patents, average survival period of a valid patent, proportion of discarded patents, one-way citation per patent, accumulative citation per patent, patent decline rate, changes in companies' quarterly net income from valid patents, the number of new patents required to replace outdated patents, companies' technology distribution, and patent maintenance rate, and attempted to evaluate patent quality with one-way citation per patent and accumulative citation per patent. Yang Wu (Yang, 1999) evaluated and identified issues the patent work of 31 universities affiliated with the Ministry of Education of China using the factors "quantity of patent applications" and "quantity of granted patents". Li Chuyan et al. (Li & Shi, 2008) were the first to use "patent quality indicator" in their study and later introduced 29 commonly used patent quality indicators at home and abroad; these indicators are divided into six categories: scientific indicators, citation indicators, international indicators, content indicators, time indicators, and other indicators. Guan Jiancheng et al. (Guan et al., 2008) used the h-index to evaluate the patent work of the top 500 companies in the field of information and communication technology and established the h-index on the basis of the citations per patent to evaluate the quality of patent portfolios. Wan Xiaoli et al. (Wan & Zhu, 2009) calculated index weights with the analytic hierarchy process; set up a patent value evaluation index system with a fuzzy mathematical method from the dimensions of technological value, market value, and the value of rights; established an evaluation index system for regional patent value from four dimensions (i.e., patent structure, patent maintenance, patent scope, and patent citation); and obtained results that could assist governmental bodies in accurately evaluating patent power within the region and in formulating appropriate policies and work plans. Yu Jingjing et al. (Yu & Tan, 2009) built an index system for the analysis and evaluation of patent portfolios based on quantity indexes representing corporate patent activities, quality indexes representing the economic and technological values of patents, and comprehensive indexes derived from weighted indexes. Li Zhenya et al. (Li et al., 2010) developed an index system with the hard system methodology proposed by American systems engineer Hall and analyzed the correlations among different dimensions with the systematic analysis method. The study focused on the theoretical deduction of the correlation between patent quality and value with the canonical correlation analysis model and developed a patent evaluation index system on the basis of the dimensions of quantity, value, and quality. Wu Jie et al. (Wu & Ye, 2012) deduced the interactive path relationship between the comprehensive power of patents and the economic development level of the region in terms of the interaction of patent input capacity, patent output capacity, and patent profitability with the labor productivity and economic development level of the region. Thereafter, the same research topics attracted the attention of scholars such as Wu Xiaoli, Tang Wei, and Shao Yong. Recent studies also reflect the growing interest in these topics. The annual key project of the National Natural Science Funds entitled "To Promote the Study on Management of the Independently-Developed Intellectual Property of China", which was presided over by Zhu Xuezhong, and the major project of the National Social Science Funds 2007 entitled "Study on Implementation of the Intellectual Property Strategy from the Scientific Development Perspective" both focused on patent quality and value indexes. The annual Youth Fund Project of the National Natural Science Funds entitled "Study on the Knowledge Management-based Commercialization Mechanism and Policies of Research Findings", which was conducted by Cao Xia, focused on a three-dimensional patent evaluation index system and the evaluation of patent value. The "Quantitative Research of the Patent Indexes used for Evaluation of Technological Innovation" led by Li Hong was listed as a project of the Shanghai Foundation for the Development of Science. The researchers defined the concept of patent capability and analyzed the necessity for knowledge-intensive companies to have such capability. They introduced the intellectual right management circulation model to assist knowledge-intensive enterprises in developing patent capability. They also used the PPM model to explore the patent distribution features of knowledge-intensive enterprises and quantitatively evaluated patent capability on the basis of the model. Ye Chuming's "Study on the Patent Measurement and Evaluation Index System" was listed as a common topic in the Shanghai Planning for Philosophy and Social Science. The State Intellectual Property Bureau later set up the "patent evaluation index system" research team to build a patent evaluation index system with consideration of patent quantity, quality, and value. They selected representative patent evaluation indexes, built the index system for regional patent evaluation, comprehensively analyzed the patent development status in the 31 provinces and regions of China with the principal component analysis method, and conducted an effective analysis of the evaluation results. The topics explored in research have greatly facilitated the study and application of patent indexes in China. Some domestic scholars have explored patent quality measurement index systems and attempted to develop a patent evaluation index system with a mathematical model. However, patent indexes have never been studied comprehensively, possibly because of the fairly recent development of this field and the resulting lack of a systematic and complete discussion of the topic.

Domestic scholars have generally focused on the exploration and analysis of domestic patents, patent quality status quo, and countermeasures from the national point of view. Their notions about the patent quality status quo of China are largely identical, except for slight differences, and their pertinent measures are worth considering. However, in view of the actual situation of Chinese patents, domestic scholars have not thoroughly explored patent development, and their analyses of patent status quo exhibit obvious deviations. By contrast, foreign scholars have thoroughly explored the propensity to file patents and the importance of high quality patents from the perspectives of patent law evolution and R&D input. Considering these factors, the present work investigates patent quality, analyzes the influencing factors of patent quality, and explores the effect of patent quality on economic development.

2. Theoretical Hypotheses and Analysis

In an open economic condition, patent quality and the benefits or satisfaction of patent owners improve when an appropriate patent system is in place. This situation reflects a typical Pareto optimality.

From the perspective of the orientation of patent systems, the humanistic environment that shapes patent systems varies depending on the region; in this way, a great distinction exists in terms of the sustainable improvement of patent quality. Max Weber pointed out in his book *The Protestant Ethic and the Spirit of Capitalism* that specific culture is the important factor that facilitates the development of capitalism. "If there is something we can learn from the development course of the economy, it will be that culture can make the situation almost completely different." The present study attempts to understand the effect of culture from the perspective of the determinants of economic prosperity. Professors Lavai and Emily chaim Wright believed that markets are integral parts of human culture that offer a venue where human beings could create colorful lives and develop a spiritual outlook. Culture embodies the economy and politics and reflects people's spiritual and material lives. Culture and tradition in different countries affect the setup and enforcement of patent systems. For example, in line with their respective cultures and traditions, the United States upholds individualism, whereas China advocates collectivism. The United States stresses the protection of inventors' benefits and prioritizes the maintenance of investors' enthusiasm for inventing. Its intentions are reflected in its implementation of a long protection period, high-priced compensation, first-to-invent principle, and regulations of employees' inventions. In China, however, safeguarding the interest of companies precedes the safeguarding of individual interests, and such condition is evident in the provisions regarding employee inventions. Moreover, China emphasizes the social share of a proprietary technology but not the exclusive privileges of patentees. Such emphasis is reflected in its implementation of a low review standard, low charge level, early publication, and low-priced compensation. Given that the patent systems of both countries have varying levels of protection effect on patent rights, their incentive effects on residents' enthusiasm for inventions and creation, as well as their effects on patent quality, tend to differ.

***Hypothesis* 1: The distinction of the orientation of a patent system may affect the improvement of patent quality.**

Suppose the marginal and average costs of Country S are the same as those of Country R. However, for the same type of patented product, the markets of these countries may encounter different followers or competitors. As a result, the demand curves of the patented product for the two countries may also be in different positions. Suppose Country S has more followers or competitors in the market than Country R. Then, the demand curve of the patented product for Country S is positioned at the bottom left position and is steeper than that for Country R. The monopoly profits are low from the patented product for the manufacturers in Country R if the product is produced in Country N. A patent in Country S could be obtained at a relatively low cost[1]; hence, the low threshold is consistent with the low exclusiveness enforced by the patent system of the

[1]The cost essentially refers to the cost that must be paid to obtain the patent rights granted by the government. It includes the costs that residents must spend in R&D, patent applications, and other aspects to meet originality, utility, and other patent granting requirements.

country. Such consistency is embodied in two aspects. On the one hand, a low threshold may cause exclusiveness to decrease. When the threshold for granting a patent application is low, a new technology can be easily modified or imitated by followers in a legal manner. That is, patent breadth is low, in which case the expected returns brought by the technology to the patentee decrease. On the other hand, when exclusiveness is low, the country needs to lower the threshold to partially compensate for the losses incurred as a result of low exclusiveness and maintain people's enthusiasm for making innovations; however, this strategy also affects people's enthusiasm for making innovations and applying for patents. In this way, the country could partially compensate for the losses incurred by low exclusiveness by reducing the cost of invention and patent application. Consequently, people obtain returns from their innovations and remain enthusiastic about innovation. Moreover, such cost reduction strategy may facilitate the engagement of more enterprises or individuals in innovation. However, Country R's patent system features high threshold and high exclusiveness (Figure 1).

From the perspective of economic outcomes, Country R widens the difference in innovation level between itself and Country M or other countries by intentionally giving powerful incentives to enterprises to innovate so as to maintain its leading position. However, the practice of Country S encourages a technical improvement within a wide scope; hence, people engage themselves in low-risk and low-input R&D, but their technological innovation lags behind that of Country R in terms of quality.

This difference may be explained by fact that the role definition of the various subjects of Country S, including the government, enterprises, and scientific research institutions, in the course of technological innovation, especially in the course of patent innovation, leads to low innovation quality. On the one hand, Country S considers the quantity of patent applications, quantity of granted patents, and patent ownership in preparing its strategic outlines of intellectual

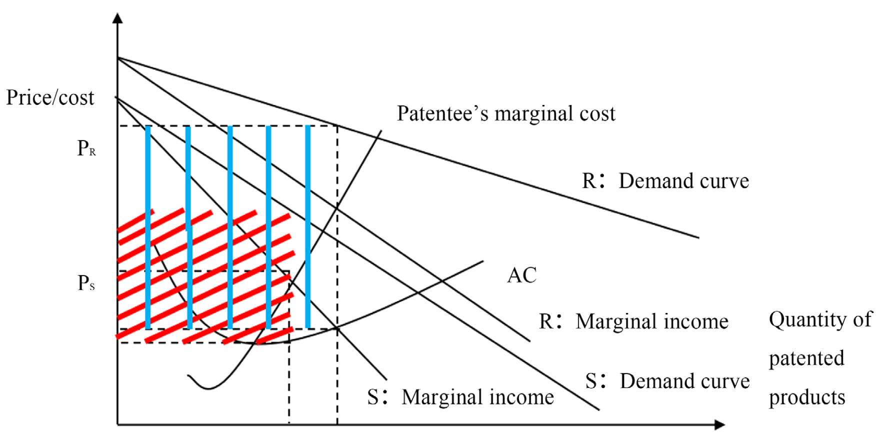

Figure 1. Difference in the overall orientations of the patent systems of country S and country R.

property rights to promote self-dependent innovation and raise patent output. Country S releases considerable financial aid policies for patent applications, aims for a high growth rate of patents, competes with others unrealistically in terms of patent quantity, and ignores patent quality. On the other hand, Country S does not examine the substance of patent applications in terms of appearance and utility design; hence, its patents are of low quality. Although such an examination system reduces public resources, it may intermingle the good and the bad and lead to the emergence of low quality patents.

For the enterprises in Country S, the insufficient investment of human and financial in patent work may affect their patent applications. Consequently, their technological achievements cannot be effectively converted into patents or be further incorporated into their competitive power. Such insufficiency may even cost them their technological achievements and result in the wastage of manpower and financial resources. This loss, in turn, seriously hinders the improvement of their sustainable development capacity and core competitiveness. Although the self-dependent innovation policies of the enterprise-based country are oriented by innovation, many enterprises use the capital appropriated from the national treasury to reimburse their cost and not to invest in R&D to improve their innovation capacity. Their reputation may increase, but their product quality and innovation quality may decline. Furthermore, some enterprises do not have a complete understanding of the prospects of some inventions or creations owing to their low capacity for patent management. Enterprises typically lack strategic analyses techniques for patents that have no value in the market at present but may take a share in the market as the technology becomes ripe. Inventors or research teams dispose of such patents haphazardly, thus failing to ensure patent quality. Some appraisals of technological achievements often highlight or depend on the quantity of patent applications. People apply for patents for the sake of applying for patents. As a result, patents fail to reach the market.

Many university scientific research institutions in Country S have set up patent funds to offer aid for patent applications or award prizes to granted patents. Some of these institutions regard patent applications and granted patents as important appraisal indexes for promotion or performance appraisal. Applying for patents can bring more benefits than writing papers, and patents are granted more easily than publishing opportunities; hence, people often emphasize the benefits brought by patents and ignore the quality or social benefits of patents. Others treat patent applications merely as a type of research finding. Significant insufficient can be found in patent quality and the maintenance and protection of patents after they are granted, and the capacity to put patents into practice is relatively low. Furthermore, the incomplete trade systems in intermediary markets force enterprises to conduct internal self-dependent R&D and engage in innovation; hence, patentees have limited access to investors. Under such conditions, patents are left idle, cannot be converted into productivity, and cannot bring economic or social benefits, all of which lead to the decline of patent quality.

Hypothesis* 2: *Customers' choice may affect the improvement of patent quality.

Social economic organizations fall into two sectors: the sector that manufactures patented products and the sector that manufactures non-patented products. The sector that manufactures non-patented products features perfect competition and develops single, homogeneous products. The sector that manufactures patented products supplies various differentiated products and is characterized by non-perfect competition and increasing returns. Potential patented products are assumed to be numerous; hence, the production space of the sector could be regarded as continuous (the product is not necessarily an integer). All consumers' preferences for both types of products are identical. According to the Cobb-Douglas production function, utility can be expressed as follows:

$$U = M^{\mu} A^{1-\mu} \tag{1}$$

where M denotes the composite index of patented product consumption, A refers to the consumption of non-patented products, and μ is a constant value that refers to the share taken up by the patented product expenditure. The composite index M is defined as the sub-utility function in the continuous space of the patented product category. The settings are as follows: m (i) represents the consumption of each available patented product, and n represents the categories of patented products and is often expressed numerically. M is assumed to conform to the constant elasticity of substitution. Then,

$$M = \left[\int_0^n m(i)^{\alpha} d_i \right]^{\frac{1}{\alpha}} \quad 0 < \alpha < 1 \tag{2}$$

where α refers to the consumers' preference for diversity in patented products. The differentiated patented products can be replaced by others perfectly when α approximates to 1. The differentiated patented products cannot be replaced in terms of function if α approximates to 0. For the equation $\delta \equiv 1/1-\alpha$, δ denotes the elasticity of substitution between any two patented products.

Y represents income, P^A denotes the price of a non-patented product (non-high-tech product), and $P(i)$ refers to the price of the i type of patented product (substitute for high-tech product). A consumer's utility maximization under the pre-specified budget constraint conditions can be expressed as

$$Y = P^A A + \int_0^n p(i) m(i) d_i \tag{3}$$

The quantity of patented product M is assumed to be enough for selection. To minimize the cost of the patented product, the following should be met:

$$\min \int_0^n p(i) m(i) d_i \quad \text{s.t.} \quad M = \left[\int_0^n m(i)^{\alpha} d_i \right]^{\frac{1}{\alpha}} \tag{4}$$

To minimize the expenditure, the first-order derivative should meet

$$\frac{m(i)^{\alpha-1}}{m(j)^{\alpha-1}}=\frac{p(i)}{p(j)} \tag{5}$$

For any i and j, $m(i)=m(j)\left[p(i)/p(j)\right]^{\frac{1}{1-\alpha}}$. On the basis of the constraint conditions of Equation (4), the following can be obtained:

$$m(j)=\frac{p(j)^{\frac{1}{1-\alpha}}}{\left[\int_0^n p(i)^{\frac{\alpha}{1-\alpha}}d_i\right]^{\frac{1}{\alpha}}}M \tag{6}$$

Next, the expenditure function can be used for the j type of the patented product, that is, $p(j)m(j)$. On the basis of Equation (6), the following equation can be obtained by integrating j.

$$\int_0^n p(j)m(j)d_j=\left[\int_0^n p(i)^{\alpha/1(-\alpha)}d_i\right]^{\frac{1-\alpha}{\alpha}}M \tag{7}$$

According to the connotation of Equations (1) and (7), the price index of the patented product expenditure is given by

$$E=\left[\int_0^n p(i)^{\frac{\alpha}{1-\alpha}}d_i\right]^{\frac{1-\alpha}{\alpha}}=\left[\int_0^n p(i)^{1-\delta}d_i\right]^{\frac{1}{1-\delta}} \tag{8}$$

After Equation (8) is substituted into (3),

$$Y=P^A A+EM \tag{9}$$

According to the consumer utility maximization principle (i.e., $\max U=M^{\mu}A^{1-\mu}$),

$$Y=P^A A+EM$$

We then obtain

$$M=\mu Y/E \quad \text{and} \quad A=(1-\mu)Y/P^A$$

We also obtain

$$m(j)=\mu Y\frac{E^{\delta-1}}{p(j)^{\delta}} \quad j\in(0,n) \tag{10}$$

According to the Dixit–Stiglitz model, the quantities and categories of the patented products are decided by consumers' demands and directly affect consumer utility. Specifically, the price of a patented product is P^M; hence, Equation (8) can be converted to

$$E=\left[\int p(i)^{1-\delta}d_i\right]^{\frac{1}{1-\delta}}=P^M n^{\frac{1}{1-\delta}} \tag{11}$$

The consumer expenditure price index reflects the quantity of patented products and depends on the elasticity of substitution δ between the patented products of different categories. When δ is smaller, a significant difference exists between the different categories of patented products. An increase in patented product categories may lead to a great decline in the price index, and vice versa.

After Equation (11) is linearized, the following can be obtained.

$$\ln E = M\ln P + \frac{1}{1-\delta}\ln n$$

$$\ln E - \delta\ln E = M/(1-\delta)\ln P + 1$$

However, consumers may raise their requirements on merchandise quality as their income increases, similar to their behavior when buying ordinary merchandise. Will patented product quality decide consumers' choice? In this work, we assume that patented product quality represents patent quality. All product quality defects that may be caused by production and manufacturing issues are considered in the analysis. That is, the quality of patented products depends entirely on patent quality.

***Hypothesis* 3: The quantity of a certain type of product chosen by consumers depends on the increase in patent quantity.**

Product quality is one-dimensional, and consumers believe innovative product A surpasses innovative product B because the former contains more patents when they are produced at the same cost; that is, the former has higher quality. An increase in the quantity of patents of every product type may result in a discrete jump in product quality. The x-coordinate in Figure 2 refers to the different product categories (i.e., the above-mentioned different categories of patented products), whereas the y-coordinate represents the different quality levels of the same product type. Each product *j* has numerous quality types, among which a vertical difference exists. In the analysis, *j* changes within the unit interval; that is, $j \in [0,1]$. $q_m(j)$ refers to the product that contains m patents in product category *j*. The quality of every new product generation is λ times that of the last generation; that is, all *m* and *j* are $q_m(j) = \lambda q_{m-1}(j)$, where $\lambda \geq 1$.

$$\log D(t) = \int_0^1 \log\left[\sum_m q_m(j)x_{mt}(j)\right]\mathrm{d}j \tag{12}$$

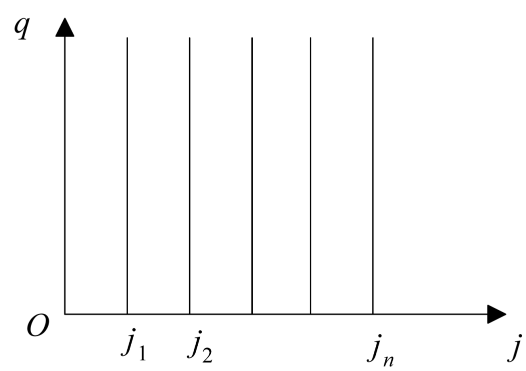

Figure 2. Quality of different categories of patented products.

where $x_{mt}(j)$ refers to the consumption of the product with quality *m* in product category *j*. At *t* = 0, product quality is equal to one unit (i.e., $q_0 = 1$). Then, $q_m(j) = \lambda^m$ is obtained. To maximize the utility $\max \log D(t)$, the derivative can be taken with respect to Equation (12) and obtain

$$x_{mt}(j) = \frac{1-\lambda^n}{1-\lambda} \tag{13}$$

Equation (13) is a monotone increasing function, that is, the quantity of a product chosen by consumers depends on the increase in patent quality, and thus conforms to the hypothesis that consumers believe that high-tech products with more patents have better quality; in this case, their tendency to choose this type of product is increased. Whether patented product price P^M and consumers' income have any effect on $x_{mt}(j)$ can be considered. On the one hand, product *j* is priced by Manufacturer A at ω. Among the products in category *j*, that of Manufacturer A has the highest patent quantity; that is, it is the leading manufacturer of product *j*. The price set by Manufacturer A is the lowest price that can secure a non-negative profit. The demand curve for the manufacturer is denoted as ABCD' in Figure 3. Although consumers are willing to pay a large sum of money for good quality products, they are likely to choose products with slightly lower quality if the price of a better product goes beyond their capacity to pay, especially in the case of high-tech products that are often expensive; in this case, the AB curve is 0. On the other hand, the manufacturer can take the 100% share in the market if the price it sets is lower than λ_ω. The CD' segment of the demand curve DD' represents the market demands for Manufacturer A's product *j*. Manufacturer A can sell any quantity of products along the BC curve if the price it fixed is the same as that fixed by its competitors when quality differentiation is not considered.

Under the constraint condition,

$$\int_t^\infty e^{-\rho t} \int_0^1 P^M(j) x_{mt}(j) \mathrm{d}j \mathrm{d}t \le \int_t^\infty e^{-\rho t} \omega(t) \mathrm{d}t + W(t) \tag{14}$$

where ρ is the subjective discount rate, $\omega(t)$ refers to the wage rate, and W

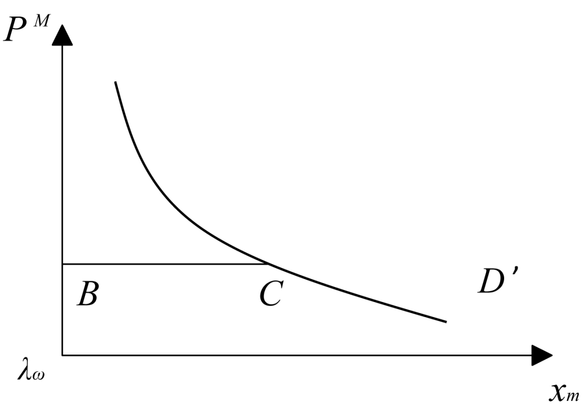

Figure 3. Demand curve for manufacturer A.

denotes the value of assets held by the family. The constraint condition refers to the situation in which the money paid for product *j* by a family cannot exceed the sum of the present value of their income from work and the value of their initial assets.

The constraint condition is equivalent to satisfying the following:

$$\mathrm{e}^{-\rho t}\int_0^1 P^M x_{mt}(j) = \omega(t) \tag{15}$$

Equation (15) shows that price is inversely proportional to consumption when income remains unchanged and that consumers choose better quality products as their income increases on the precondition that the price remains unchanged.

Given that $E = P^M n^{1/1-\sigma}$, the following can be obtained after Equation (4) is substituted into it: $\mathrm{e}^{-\rho t}\int_0^1 \frac{E}{n^{1/1-\sigma}} x_{mt}(j) = \omega(t)$, after Equation (13) is substituted into it, the following can be obtained:

$$\int_0^1 \frac{1-\lambda^n}{n^{1/1-\sigma}(1-\lambda)} = \frac{\omega}{E\mathrm{e}^{-\rho t}} \tag{16}$$

Given that *n* refers to the number of patented product categories and that λ denotes the increase in patent quantity, *n* is equal to the total quantity of the patents of patented products. The initial quantity of the patents of product *j* is 0. The following equation can be obtained by calculating the limit of Equation (16):

$$\frac{2}{n^{1/1-\sigma}\left(2-n^{1/1-\sigma}\right)} = \frac{\omega}{E\mathrm{e}^{-\rho t}} \tag{17}$$

The equation indicates that the substitution elasticity among different categories of patented products is subject to the influence of income, price index, and consumers' subjective discount rate. The categories of patented products relate to patent quality. Therefore, the influencing factors of patented product quality, which represent patent quality, are residents' income, patented product price, and patented product categories.

When the influence of price on consumers' appraisal of patent quality is not considered, the relationship between the increase in patent quantity λ and the consumption $x_{mt}(j)$ is that shown in **Figure 4**. This figure shows the variation trend of $x_{mt}(j)$ as the increase in patent quantity λ and the number of patent categories *n* change. Moreover, the figure indicates that $x_{mt}(j)$ increases if λ increases. At the same time, the consumption of a product is high if the number of patented product categories is high. Consumers believe that this type of patented product has better quality if λ and *n* are high; thus, the consumption of the product is also high.

The following is the situation in which consumers' income and patented product price are considered. **Figure 5** shows that $x_{mt}(j)$ increases along with time if consumers' subjective discount rate is set to $\rho = 0.7$ and their income are a constant value. $x_{mt}(j)$ Shows a significant declining trend when the P

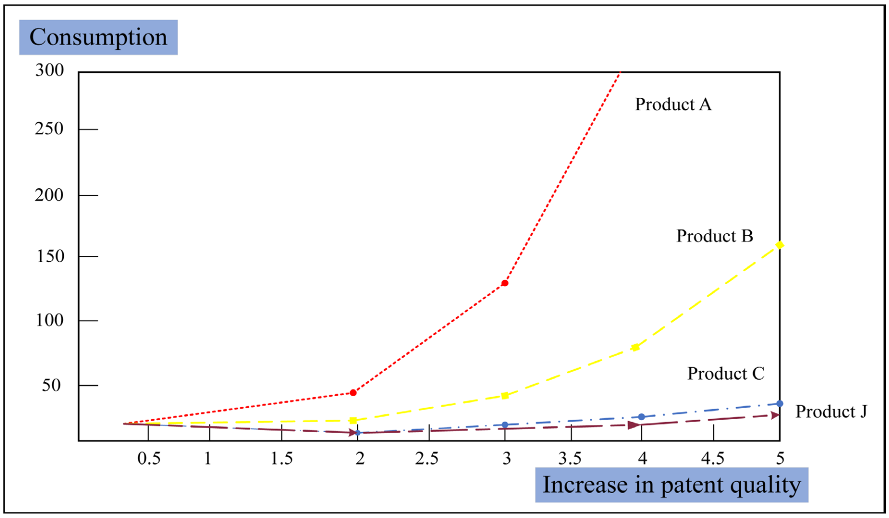

Figure 4. Relationship between the increase in patent quantity and the consumption of different categories of patented products.

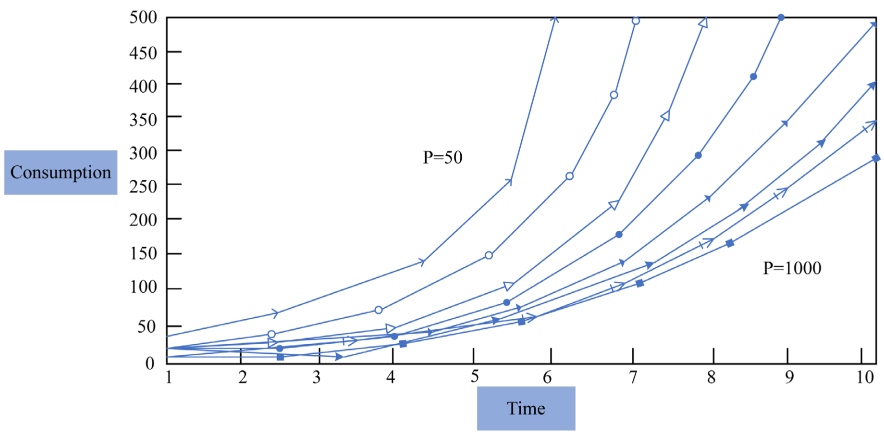

Figure 5. Variation trend of consumption as price changes but with subjective discount rate and wage level kept unchanged.

value increases. However, the curves show a similar shape as a whole, thus indicating that consumers may choose products according to their affordability even when prices continue to rise. The consumption of high-priced patented products within the same time interval is obviously lower than that of high-priced products. Figure 5 shows that the increase of $x_{mt}(j)$ leads to the increase of λ and to the decline of the price to a low price interval. This condition indicates that consumers prefer to choose products that contain many patents but have a low price, thereby verifying the previous hypothesis. Knowledge resources for high-tech enterprises are crucial to the improvement of their profitability and competitiveness. Therefore, enterprises should consider the ROI of patented products before they release any patent to the market. Figure 4 and Figure 5 show that low-priced products may take a shorter time to achieve $x_{mt}(j)=300$ compared with high-priced products. According to the model, the optimum increase in patent quantity can be obtained for the same type of product in the same sector ($x_{mt}(j)=300$, $\lambda=3.5$). Sales volume can be increased simultaneously when cost is saved. If the marketability and industrialization degree of a patented product is high, then patent quality is relatively high.

3. Building and Analysis of Simple Model

3.1. Sample Selection and Data Collection

We analyze the patent-related data of poly-crystalline silicon, an emerging material used for the production of solar cells to simplify the explanation for the above-mentioned analysis. The data comprise the income data drawn from the China Statistical Yearbook 2002-2012, the data regarding the patent of poly-crystalline silicon from the solar cell category of the "Seven Countries and Two Organizations" Patent Database, and the data about the rate of complaints made over the Internet regarding poly-crystalline silicon-based solar cells.

3.2. Definition of Variables

1) *Income*. The index mainly reflects consumers' affordability; hence, the per capita income of the period 2002-2011 is selected. The median income is determined. The group of residents whose income is above the median value is deemed as the high-income group, whereas the group of residents whose income is below the median value is deemed as the low-income group.

2) *Price*. Poly-crystalline silicon has been widely used in the production of solar cells. The manufacturing cost and price of the raw material are low, and the material's conversion efficiency is as high as 15%. Moreover, consumers may also consider the adaptability of solar cells to power and voltage; hence, we select each year's quoted market price of the 100 W 36 V poly-crystalline silicon solar cells as the price of the patented product.

3) *Category*. The quantity of granted patents is used as a substitute for the categories of the patented product on the basis of the hypothesis stating the existence of two sectors: the sector that manufactures patented products and the sector that manufactures non-patented products. The granted patents correspond to the categories of the poly-crystalline silicon. The logarithm is determined in the subsequent analysis. The annual number of patent applications is also introduced into the comparative analysis. All the above-mentioned data are obtained from the website of the Intellectual Property Office.

4) *Complaint rate*. The complaint rate of the product is used as the index substituted for patented product quality. On the basis of the availability of data, we collect the annual average complaint rate of over 10 companies related to the online sales of poly-crystalline solar cells as the index for measuring patented product quality. The formula complaint rate (CR) = number of complaints (C)/total purchases (total) is used as the analysis index in the following analysis.

3.3. Descriptive Analysis

We use Stata12.0 to process and analyze the data.

Figure 6 shows that the categories of the patented poly-crystalline solar cell product increase yearly. The increase in the applications for relevant patents also indicates that the potential of the product and the importance attached by the market to the product are increasing. The increase in product categories is bound to affect product consumption. Whether this increase affects the patented product quality is yet to be determined.

Figure 7 shows that the spots representing a low complaint rate are concentrated at the bottom right corner. The product quality in this situation always surpasses the quality of the product with few categories and high price. This outcome is consistent with the hypothesis stating that people believe that the quality of a product with more patents is relatively superior to that of a product with fewer patents. The outcome also supports the notion of consumers that a product with more patents and lower price is excellent and has better quality. On the contrary, the top left corner of Figure 7 shows that a solar cell with few categories and high price is faced with a high complaint rate; that is, when consumers pay attention to product performance, their quality evaluation is affected

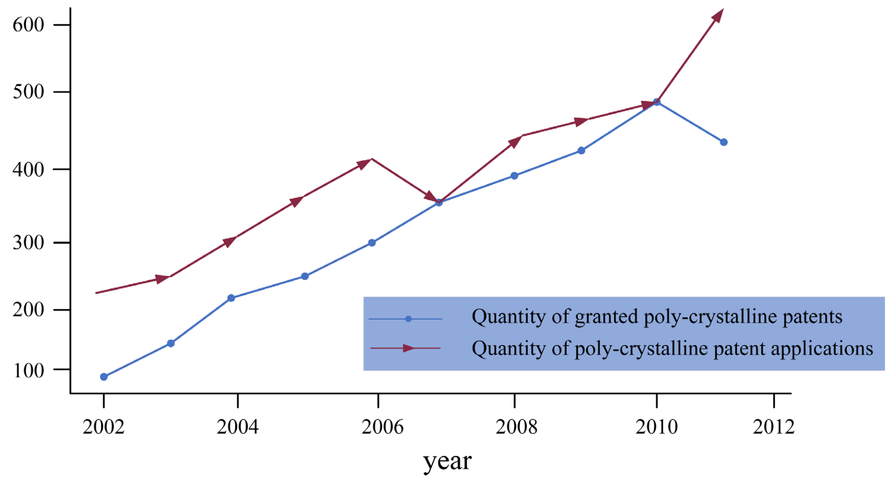

Figure 6. Categories of patented poly-crystalline solar cell product, quantity of patent applications, and quantity of granted patents.

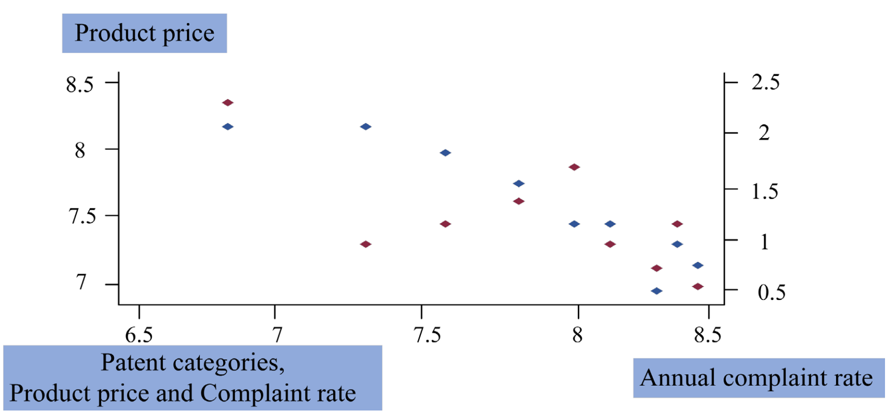

Figure 7. Price and complaint rate of patented poly-crystalline solar cell product.

by product price.

Income falls into two categories: high income and low income. We explore the effect of product quality on consumers' complaint rate under the two income levels. Low-income consumers have relatively low purchasing power. The distribution of the spots in the diagram illustrate that an increase in price does not decrease the quality appraisal. Low-income consumers often believe that when a product has a high price, it likely deserves such price. Therefore, a low-income consumer who buys a high-priced patented poly-crystalline solar cell product tends to give a high appraisal. The overall trend of the spots is upward and is mainly concentrated at the bottom left corner when the income is high. The complaint rate of high-income consumers is low when the product is cheap. High-income consumers see little hope of getting good quality from a cheap product when they buy it. They may give a positive comment randomly or rationally believe and accept that a cheap product is imperfect. Thus, the spots in Figure 8 are concentrated at the bottom left corner. The complaint rate for a high-priced product is low because an increase in the costs of product processing, technologies, and raw materials improves the quality of the product. However, highly over-priced product tends to suffer from complaints because of consumers' high expectations about the product.

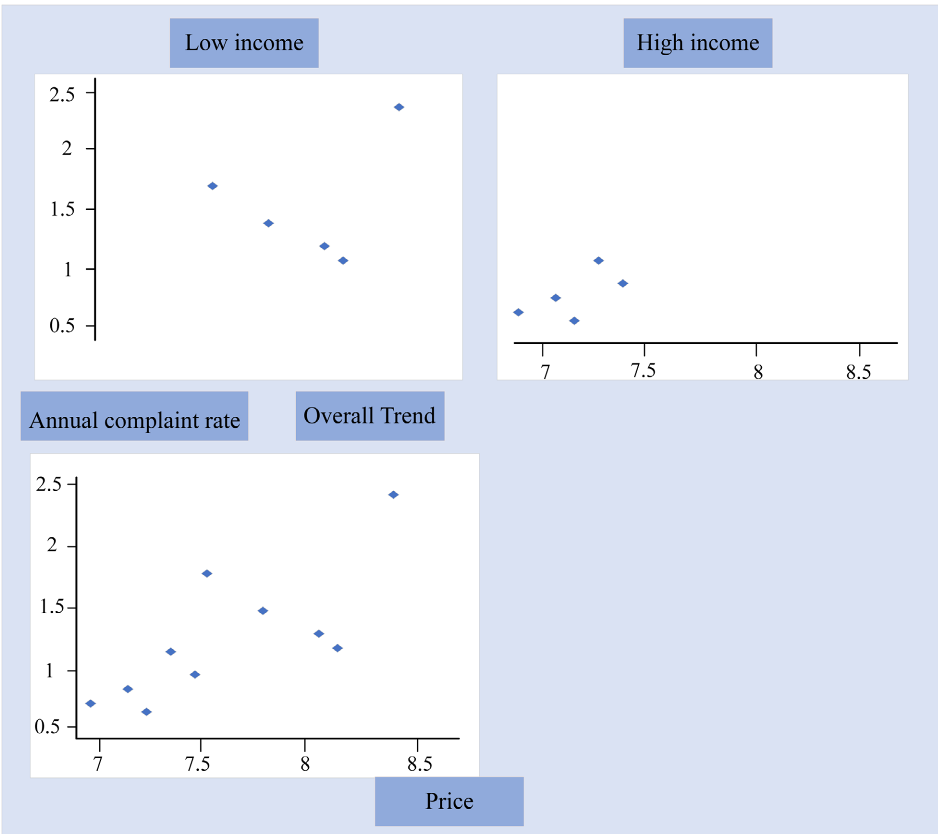

Figure 8. Relationship between price and complaint rate of a patented product under different income levels.

3.4. Verification via Measurement Model

The results of the theoretical model and the results of the direct graphical analysis reveal the following: the complaint rate declines as the per capita income or consumers' purchasing power increases, the complaint rate of a high-priced product is lower than that of a cheap product in most cases, and an increase in patent quantity allows consumers to believe that the quality of the patented product is improved (in which case the complaint rate decreases). Therefore, we sum up the three hypotheses as follows:

H_1: Per capita income is negatively correlated with the complaint rate of patented product.

H_2: The price of a patented product is negatively correlated with the complaint rate of the patented product.

H_3: An increase in patented product categories is positively correlated with the improvement of patent quality.

We verify and analyze the hypotheses with a simple measurement model.

3.5. Correlation Analysis

Table 1 shows the correlation among all variables. The logarithm of all the variables is determined before the data are processed. The verification results show that price is positively correlated with complaint rate ($p < 0.1$), whereas patent categories and income are negatively correlated with complaint rate. This outcome is consistent with the discussion results in the previous section. A significant positive correlation is found between categories and price, and a significant negative correlation is noted between income and categories. The relationship among the variables is further verified and analyzed through the model in the following sections.

3.6. Model Assumption

$$CR = \beta_0 + \beta_1 \log \text{price} + \beta_2 \log \text{category} + \beta_3 \log \text{income}$$

where CR denotes the complaint rate, which is an explained variable and represents the quality of poly-crystalline solar cell product. Log price refers to the logarithm of the poly-crystalline solar cell price, log category is the logarithm of the quantity of granted poly-crystalline solar patents, and log income is the logarithm of the per capita income.

Table 1. Analysis results of the correlation among all variables.

Variable	1	2	3	4
1) CR	1.0000			
2) Price	0.6032*	1.0000		
3) Category	−0.7322	0.9200**	1.0000	
4) Income	−0.6887	−0.9609*	0.9174	1.0000

Note: $^*p < 0.1$, $^{**}p < 0.05$.

3.7. Verification Results and Discussions

According to the analysis results in Table 2, the correlation coefficients of patent price, patent grant and per capita disposable income with the complaint rate are about 0.14, −0.09 and −0.14, respectively, but the per capita disposable income does not pass the test of significance, i.e., the variable cannot explain the complaint rate well, so the patent price and the patent grant are the most important factors affecting the complaint rate, i.e., the patent price is positively correlated with the complaint rate. Therefore, patent price and patent license quantity are the most important factors affecting the complaint rate, i.e. patent price is positively related to the complaint rate and patent license quantity is negatively related to the complaint rate, which will be analyzed in detail below: people tend to choose higher-priced poly-crystalline solar cells as the per capita disposable income increases yearly. The quality of high-priced products in the market is generally better than that of low-priced products; hence, the complaint rate decreases yearly. However, the variable does not pass the significance test, although it is positively correlated with the explained variable. The income has a regulating effect, as analyzed in the previous sections. The unit price of a poly-crystalline solar cell passes the significance test but is positively correlated with the explained variable. That is, the second hypothesis does not pass the verification. This result indicates that an increase in price may cause the complaint rate to rise. An expensive product is superior to a cheap product in terms of quality. Thus, consumers' complaints about patented products decrease. However, consumers may raise their expectation for a product as the price rises to an extremely high level. Thus, consumers may complain if the product does not achieve the utility they expect on the basis of the price even in the absence of a serious quality issue. Therefore, the final verification results are positively correlated, and an overly high price is not conducive to the improvement of patented product quality. The quantity of granted patents also passes the significance test and is negatively correlated with the complaint rate. That is, the third hypothesis does not pass the verification. Our previous hypothesis stating that consumers believe that a patented product with more patents has better quality is an ideal and simple hypothesis. However, although people subconsciously believe that a product containing more patents has better quality than those with fewer patents and thus prefer to buy the former, they have extremely high expectation for the

Table 2. Multiple regression analysis results.

Variable	Model
Price	0.1421533* (−1.30)
Category	−0.0921831* (−1.42)
Income	−0.1460319 (−1.09)
Cons	3.297618 (1.65)

former. In most cases, the description of various patents in merchants' advertisements is merely to publicize their product and make their product appealing to consumers when, in fact, the quality of their product has not been improved greatly within a short term. Therefore, a gap emerges between the actual situation and consumers' expectation. According to prospect theory, people's sensitivity to loss is higher than their sensitivity to returns. Consumers rationally believe that products should have better quality when such products have more patents. However, merchants' speculative behavior results in a psychological gap to consumers. Consumers complain when their satisfaction decreases.

4. Conclusions and Innovations

In recent years, with the substantial growth in the number of patent applications and authorizations as well as the lowering of the threshold for patent applications and approvals, more and more problematic patents have appeared in the market, which not only disturb the normal market order, but also reduce the promotional effect of patents themselves on the main body of innovations, such as enterprises or institutions, and therefore, the improvement of the quality of patents has been more and more emphasized by countries all over the world, and China is no exception. Although many scholars have carried out extensive research on this issue and provided certain constructive opinions, from the perspective of the actual situation of Chinese patents, scholars have not explored the patent issue in depth enough. Considering the shortcomings of the current research field of patent quality, this paper carries out a more in-depth and detailed research on patent quality, and utilizes mathematical derivation and model validation to explore the key factors affecting patent quality. It also explores the impact of patent quality on economic development, and finally puts forward more reasonable and practical policy suggestions based on the research results.

The main conclusions of the article are as follows:

1) The relevant systems introduced by the state and the government can affect the quality of patent products in the region, and the appropriate patent system can improve the patent quality of the region to a certain extent, and the behavior of the government, enterprises, university research institutions and intermediaries as the main body of innovation will also affect the patent quality.

2) Patent price and patent grant are important influencing factors of patent quality. Income has a moderating effect on patent quality, with the per capita disposable income increasing year by year, people tend to choose higher priced patent products. The quality of high-priced products in the market is generally better than that of low-priced products, so the complaint rate decreases year by year, which indicates to a certain extent that the quality of patents has been improved to a certain extent, but the influence relationship between it and the quality of patents is not obvious; the rising price of patented products will lead to the increase of the complaint rate, i.e., the lowering of the patent quality, and the high-priced products are generally better than the low-priced ones in terms

of quality. The complaints of patent products will be reduced, however, if the price breaks through a certain threshold, consumers will raise the expectation of the product, even if the quality of the product does not have a big problem, when the utility of the product of that price fails to reach the psychological expectation of the consumers, the consumers will complain, therefore, too high price is not conducive to the improvement of the quality of the patent products; the number of patents granted and the rate of complaints are in a negative correlation, i.e., the increase of the number of patents granted will improve the patent quality, and an increase in the number of patents granted usually means higher quality patents, as higher quality patents are less likely to be challenged and disputed.

5. Suggestions

As the global economy struggles, the different innovation subjects of China should expand their intellectual property rights abroad by improving patent quality to increase the share of domestic products in the international market.

The government should strengthen the macro-management of patents, use patents to promote industry innovation, consummate patent-related aid and incentive policies, and establish a review and inspection system for applicants and technologies to guarantee the efficient utilization of the applicants' own funds. Moreover, the government should arrange a supporting mechanism for patent funds, as well as a profit returning mechanism after patented technologies are commercialized, and generate profits, thereby forming a virtuous cycle of "funding-applying-commercializing-profit returning-increasing funds".

Innovation subjects should invest into R&D actively, strengthen their absorption and understanding of introduced technologies, improve independent innovation and re-innovation of introduced technologies, and enhance enterprises' capacity to manage and use intellectual property rights.

The scientific research institutions of universities should emphasize the actual commercialization capacity of patents and the improvement of patents' market value. They should promote the commercialization of technological achievements by working with enterprises.

Patent intermediary agencies and the market for patented technologies should be improved constantly. Industry associations and other related organizations should assist innovation subjects in setting up relevant technical alliances ("patent tool"), promoting the conversion of relevant technologies into industry technical standards, and optimizing the policies and system for patent exploitation, licensing, transfer, pledge, and appraisal as capital stock.

A reasonable platform should be set up among the government, enterprises, scientific research institutions of universities, and patent intermediary agencies to track the technology development tendencies through patent or patent exploitation. These subjects should then secure a share in the technical market through self-dependent innovation.

In the context of economic globalization, one cannot win the "patent battle" in the market competition until the focus is shifted from the quantity of patents to both the quality and quantity of patents. All innovation subjects are required to attach importance to the improvement of patent quality. Doing so allows subjects to use patents to promote industry innovation, create an innovative country, enhance the country's scientific and technological strength, and further gain an edge in the global economic competition.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Guan, J. C., Gao, X., & Xu, N. L. (2008). Evaluation of Patent Quality Based on h-Index and International Comparison. *Studies in Science of Science, No. 5,* 932-937.

Hirschey, M., & Richardson, V. J. (2004). Are Scientific Indicators of Patent Quality Useful to Investors? *Journal of Empirical Finance, 11,* 91-107. https://doi.org/10.1016/j.jempfin.2003.01.001

Hu, Y. (2007). Preparation and Implementation of Industry Patent Strategies. *Management World, No. 8,* 165-166.

Li, C. Y., & Shi, R. (2008). Exploration on Patent Quality Indicator Evaluation System. *Modern Information, No. 2,* 146-149.

Li, Z. Y., Meng, F. S., & Cao, X. (2010). Study on Three-Dimensional Evaluation System of Patents. *Information Science, No. 10,* 1569-1573.

Ma, Z. F. (2010). A Reconsideration of Patent Essential Connotation and Mission of Patent System from the Perspective of a Low Patented Technology Commercialization Rate. *Science& Technology Progress and Policy, 27,* 99-102.

Nicholas, T. (2011). Did R&D Firms Used to Patent? Evidence from the First Innovation Surveys. *Journal of Economic History, 71,* 1032-1059.

Schankerman, M., & Pakes, A. (1986). Estimates of the Value of Patent Rights in European Countries during the Post-1950 Period. *Economic Journal, 97,* 1-25. https://doi.org/10.3386/w1650

Thomas, J. R. (2002). The Responsibility of the Rule Maker: Comparative Approaches to Patent Administration Reform. *Berkeley Technology Law Journal, 17,* 728-761.

Wan, X. L., & Zhu, X. Z. (2009). Status and Trends of Patent Quality Indicator Research in International Perspective. *Journal of Intelligence, No. 7,* 50-54.

Wang, X. L., & Zhu, X. Z. (2008). The Indicator System and Fuzzy Comprehensive Evaluation of Patent Value. *Science Research Management, No. 2,* 185-191.

Wu, J., & Ye, C. M. (2012). Measurement of the Contribution of Patent Output in Central Region to Economic Growth. *Productivity Research, No. 5,* 95-98.

Yang, W. (1999). *Technological Innovative Property Right* (pp. 87-89). Tsinghua University Press.

Yu, J. J., & Tan, S. M. (2009). Application of the Evaluation Index System of Patent Portfolio Analysis. *Journal of Intelligence, No. 12,* 152-155.

Yuan, X. D., & Liu, Z. L. (2011). Patent Quality Problems and Coping Strategies. *Science and Technology Management Research, No. 9,* 156-160.