# STUDY ON SUSTAINABLE DEVELOPMENT OF TECHNICAL CREATIVITY

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*The number of patent applications can provide information on the level of economic development of a country. It is higher in the case of industrially developed countries. An analysis of the evolution of the number of patent applications over a certain period in the case of some countries was undertaken. Mathematical models of regression type were determined for modeling the evolution of the number of patents. A performance indicator determined as a ratio between the number of patent applications and the number of inhabitants of a country during a year is considered to provide information on the sustaining level of the state towards an innovative society.*

**Keywords**: technical creativity, evolution, patent development, patent application, regression analysis, key performance indicators.

## 1. Introduction

The concept of *creativity* takes into account the ability of a person, through his efforts, to arrive at original and effective solutions to the problems he/she faces. Over the years, numerous definitions of the concept of creativity have been formulated, reflecting the interest of society and researchers to ensure such conditions so that creativity can fully manifest itself.

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In the field in which creativity is exhibited, concepts such as *technical creativity*, *scientific creativity*, *artistic creativity*, etc. can be considered, with specific features, as appropriate.

Thus, for instance, *technical creativity* characterizes a person's ability to identify original and effective solutions to the technical problem for which he/she is trying to find one or more solutions.

One of the ways to materialize creativity, especially in the field of engineering, but also in other fields, is to develop some invention proposals, for which the concept of *patent applications* is also used in various works.

It is to be noted that, according to the currently valid regulations, a technical solution is patentable if it is new, if it results from the inventive activity, and if it is susceptible to application in practice [1, 2].

It is normal for researchers to be concerned about reaching patentable technical solutions through engineering design activities.

Thus, Huang et al. considered the expansion of so-called collaborative creativity, with the involvement of a large number of inventors, due to the facilitation of communication through technologies that appeared in the last decades [3]. They appreciated that this collaborative creativity tends to globalize, but remains a characteristic, especially of economically advanced states.

Vasantha et al. set out to investigate the role of patents in engineering design. They concluded that patents can be used effectively if a systematic and long-term approach to them is followed and if there is a basic level of understanding of the solutions by those involved in solving technical problems [4].

A certain correlation between the number of patent applications and the so-called Global Innovation Index was noticed in the case of the Republic of Moldova by Golban and Golban [5].

Siddharth et al. thought that a certain type of knowledge graph could contribute to increasing the efficiency of engineering design processes. They proposed ways of extracting certain information from patents in such a manner as to facilitate the consultation of the patents and the operational understanding of the essential information in them [6].

The possibility of parallel inventions developing similar technical solutions was analyzed by Kang et al. [7]. They concluded that such parallel inventions occur especially when the inventors have access to the same sources of information and when they have possibly also exchanged opinions with each other.

By patenting, the invention author is given the right to benefit, for a certain period, from the right of ownership over the proposed solution. However, it is to be noted that, by applying the current legislation related to inventions, a real obstacle could arise for faster expansion of technical progress, since solutions under protection may not be used without the consent of the invention owner [8].

On the other hand, the identification of patentable solutions and the registration of patent applications may be part of a state's economic policy. An examination of the number of patent applications submitted annually by some countries leads to a list in which, in the first place, there are some either highly industrialized countries or countries that are pursuing accelerated industrial development [9-16].

The scientific, technical, and/or economic developments based on the valorization of patents, as revealed, for example, by [17-21], represent major innovative achievements.

A recognized method of evaluating the performance of a process or system is based on the use of appropriate key performance indicators. [22].

The study of the information identified in the specialized documentation highlights the interest given in economically developed countries to the promotion of technical solutions capable of leading to the improvement of products and processes.

The identification of such solutions can be a result of the use of effective methods to stimulate the technical creativity of people involved in technical activities, but also of an atmosphere that encourages the participation of specialists in the process of generating new technical solutions. It is also necessary to know the regulations regarding the protection of industrial property rights and those regarding the preparation of documents specific to patent applications.

The purpose of the present paper is to analyze the evolution of patent application numbers, based on actual statistical data concerning patent applications in a series of industrial countries, to reveal the main characteristics of patent trends with a potential development perspective and the corresponding major influencing factors.

## 2. The pace of materializing technical creativity through patenting

In principle, the patent is a way of protecting the person's rights over a technical solution. Society considered that a person who contributed to the identification of a solution to a technical problem should benefit, at least for a certain period, from the results of his investment of effort in solving the technical problem.

Over the last decades, specific ways of preparing the documents corresponding to a patent application have been gradually outlined, including the contribution of international organizations established for this purpose.

It can also be mentioned that a patent is a document that can certify the worldwide priority of formulating a solution to a certain technical problem.

There is a certain connection between technical creativity and patenting activities, the identification of an original technical solution claiming a direct involvement of the technical creativity of one or more people.

It is thus expected that the stimulation of technical creativity, by the various structures of a state, will also lead to an increase in the number of patent applications filed in that state at a certain time.

An attentive broad analysis of patent generation and application process reveals their specific characteristics, such as significance, application area, trendline, level of sustainable impact, main influencing factors, etc., as well as a potential development perspective.

A regression analysis of the patent development in a few countries, based on statistical data, as presented in Table 1, has been unrolled as follows.

*Table 1*

**Number of patents [9-16, 23-25]**

| Year | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| Germany | 44396 | 39157 | 86070 | 139451 | 156615 | 59245 | 175559 | 168092 | 157652 |
| USA | 115170 | 170822 | 228238 | 315015 | 417508 | 520277 | 629647 | 646244 | 515281 |
| China | 8535 | 10124 | 11199 | 29227 | 124035 | 391177 | 1010557 | 1441086 | 1619268 |

Let us consider the general period, $TP$, 1985 – 2022, a certain year, $Y$, and the relative year of analysis, $T$, so that:

$$TP = [1985, 2022],\ Y \in Yv.\tau,\ Yv.\tau \subseteq \{1985, 1990, \ldots, 2020, 2022\} \quad (1)$$

$$T = Y - 1985 \Leftrightarrow T \in Tv.\tau,\ Tv.\tau \subseteq \{0, 5, \ldots, 35, 37\}, \quad (2)$$

where $\nu$ and $\tau$, $\nu, \tau = 1, 2, \ldots$, are associated with different categories of conditions (country, effective period, etc.), as the case.

Let us consider, also, the regression functions which represent the evolution of the patents number, $P$, in dependence on the relative year of analysis, $T$, as a linear function, power function, etc. [26], as the case, i.e.:

$$P\nu.\tau = P(T) \Leftrightarrow P\nu.\tau = a_0 + aT \text{ or } P\nu.\tau = b_0T^b, \text{ etc.}, \ \nu, \tau = 1, 2, \ldots, T \in Tv.\tau \quad (3)$$

The suitability level of a determined regression function is overall evaluated by the coefficient of determination $R^2$ [27, 28], where $R^2$ has to be of high value and:

$$R^2 \in (0; 1] \quad (4)$$

Among a set of regression functions $P1.1$, $P1.2$, …, the acceptable one, for the considered actual data, is chosen based on the selection criteria as the trendline feature to envisage a potential development perspective and the coefficient of determination value ($R^2$).

In the case of the patent development in Germany, among several linear, power, or polynomial regression functions, the relevant ones are of a linear type and associated with all actual data, as presented in Fig. 1 and eq. (5); those actual data within which the number of patents is of monotonically increasing value, as presented in Fig. 2 and eq. (6).

It is to be noted that the unexpected values of actual patent number $P$ for $T$ values of 5, 25, 35, 37 ($Y$: 1990, 2010, 2020, 2022), as presented in Fig. 1, could be in correlation with events which largely affected the socio-economic system, as, e.g., the critical actions of Covid-19 during 2020 - 2022. Overall, the $P1.2$ regression function is found to be acceptable for the considered actual data.

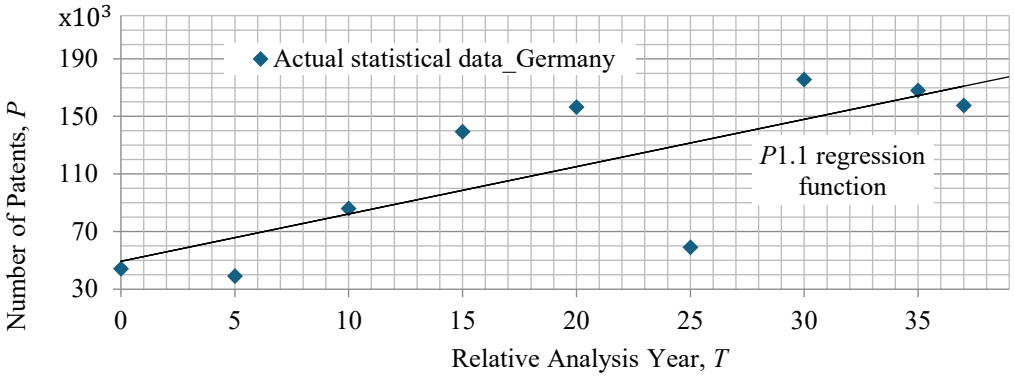


Fig. 1. Data on $P1.1$ regression function_Germany (based on data from Table 1)

$$P1.1: P = 3286.8T + 49385,\ T \in T1.1 = \{0, 5, \ldots, 35, 37\};\ R^2 = 0.5925 \quad (5)$$

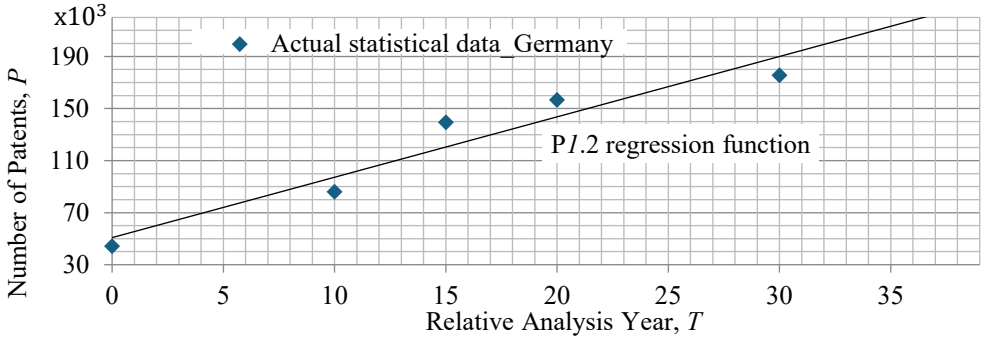


Fig. 2. Data on $P1.2$ regression function _Germany (based on data from Table 1)

$$P1.2: P = 4640.3T + 50813,\ T \in T1.2 = \{0, 10, 15, 20, 30\};\ R^2 = 0.9224 \quad (6)$$

In the case of patent development in the United States of America (USA), among several linear, power, or exponential regression functions, the relevant ones are of linear type and associated with all actual data, as presented in Fig. 3 and eq. (7); those actual data within which the number of patents is of continuously increasing value, as presented in Fig. 4 and eq. (8). It is to be noted that, in comparison with the trend of annual increasing rate, there are lower values of actual patent number $P$ for $T$ values of 0 and 35 ($Y$: 1985, 2020) and a much lower value of $P$ for $T$ value of 37 ($Y$: 2022), as presented in Fig. 3; the figures corresponding to 2020 – 2022 could be mainly in correlation with unfavorable actions of Covid-19. Overall, the $P2.2$ regression function is found to be acceptable for the considered actual data.

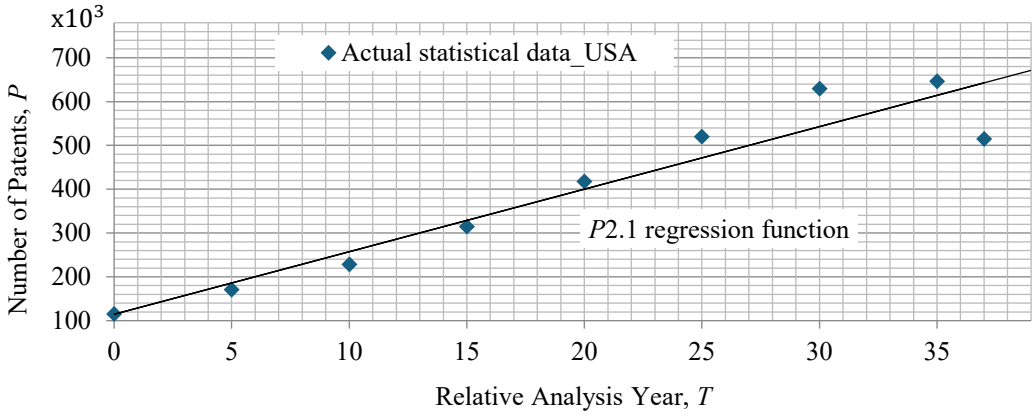


Fig. 3. Data on $P2.1$ regression function_USA (based on data from Table 1)

$$P2.1: P = 14275T + 114607,\ T \in T2.1 = \{0, 5, \ldots, 35, 37\};\ R^2 = 0.9077 \qquad (7)$$

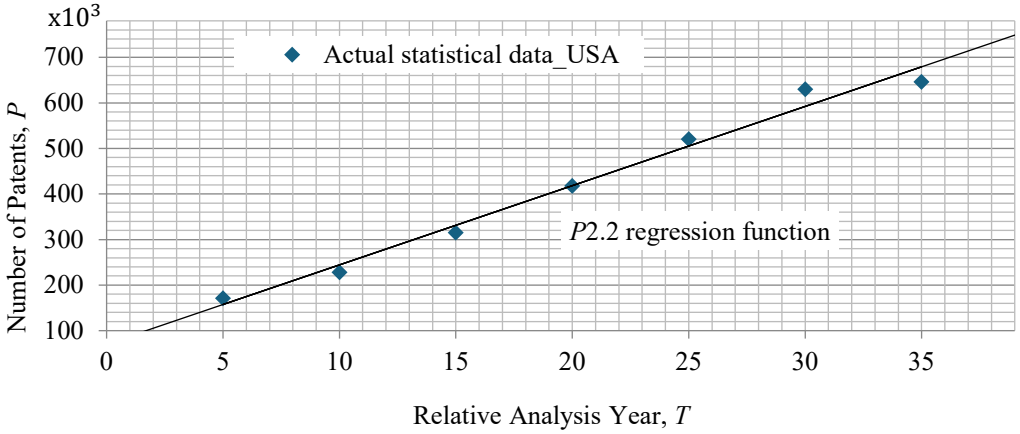


Fig. 4. Data on $P2.2$ regression function_USA (based on data from Table 1)

$$P2.2: P = 17338T + 70486,\ T \in T2.2 = \{5, 20, \ldots, 35\};\ R^2 = 0.9841 \qquad (8)$$

In the case of patent application development in China, the initial analysis of the actual statistical data (Table 1) reveals a few periods characterized by different increasing rates of patent numbers.

Further, for each analyzed period, several linear, power, or exponential regression functions have been subjected to selection criteria. The acceptable model is constituted through a group of regression functions defined on certain periods, as presented in Fig. 5 and eq. (9).

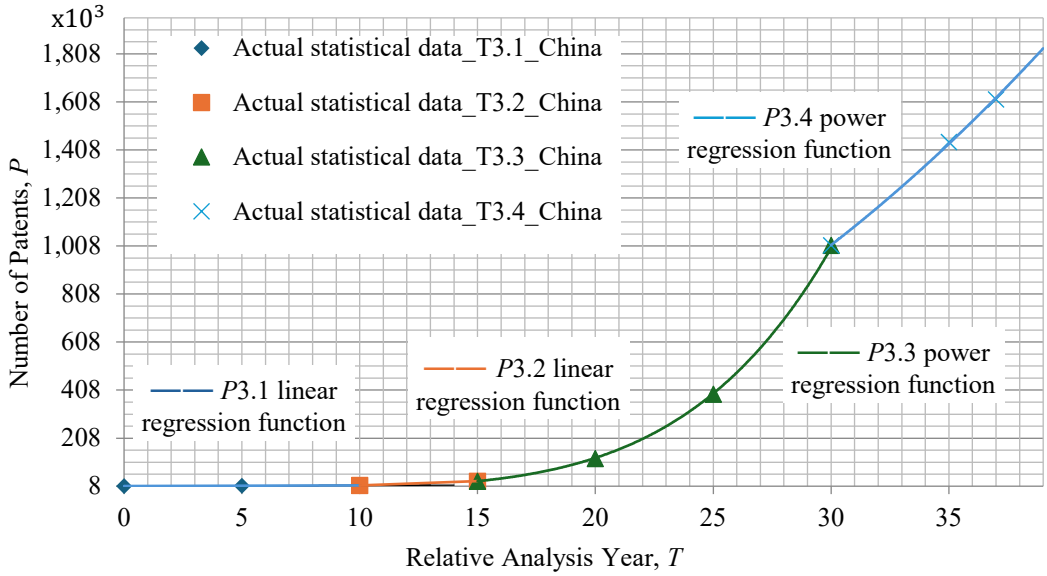


Fig. 5. Data on the regression functions_China (based on data from Table 1)

$$P3.1\text{: } P = 266.4T + 8620.7,\ T \in T3.1 = \{0, 5, 10\},\ R^2 = 0.9877;$$

$$P3.2\text{: } P = 3605.6T - 24857,\ T \in \mathrm{T}3.2 = \{10, 15\},\ R^2 = 1;$$

$$P3.3\text{: } P = 0.0282T^{5.1109},\ T \in T3.3 = \{15, 20, 25, 30\},\ R^2 = 0.9999;$$

$$P3.4\text{: } P = 464.81T^{2.2597},\ T \in T3.4 = \{30, 35, 37\},\ R^2 = 0.9995 \qquad (9)$$

Further, an analysis of the efforts of states to encourage innovation by increasing the number of patents developed by their citizens, is unrolled, based on *the key performance indicator*, *p*, defined as the number of patents per one million inhabitants, i.e.:

$$p = 10^6 P/I, \qquad (10)$$

where, for a certain country and year, $P$ represents the number of patents, and $I$ - the number of inhabitants.

The statistical data on *P* and *I* for some countries (Republic of Korea, Japan, Germany, Netherlands, U.S.A., China, România), as well as the calculated values for the key performance indicator *p*, are presented in Table 2 and the corresponding chart from Fig. 6.

*Table 2*

**Number of patents, number of inhabitants [23-25, 29-33] and *p*, year 2022**

| Country | Republic of Korea | Japan | Germany | Netherlands | U.S.A | China | România |
|---|---|---|---|---|---|---|---|
| *P* | 272675 | 406374 | 157652 | 32738 | 515281 | 1619268 | 1140 |
| *I* | 52321152 | 124370947 | 84270625 | 18009600 | 343477335 | 1422584933 | 19118479 |
| *p* | 5212 | 3267 | 1871 | 1818 | 1500 | 1138 | 60 |

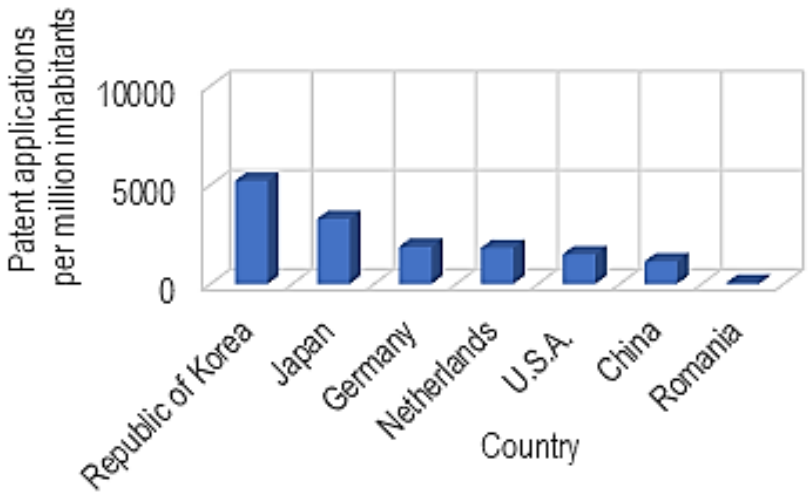


Fig. 6. A chart of patents number per one million inhabitants, in 2022

The result of the considered analysis represents an important expression of the efforts level of different states in sustaining the development of an innovative society.

The mathematical models corresponding to the evolution of the number of patent applications submitted annually in the different countries, when such models are appropriate, provides direct information on the involvement of specialists from the respective countries in the activities of identifying and protecting industrial rights on new technical solutions.

It is worth noting the significant increase in the number of patent applications in China in recent years, proving the interest of the government authorities to improve China's position from this point of view.

Even if the use of an indicator that takes into account the number of patent applications to the number of inhabitants of a country does not yet ensure China a leading position from this point of view, it is expected that if the annual growth rate of the number of patents applications in China continues to be high, the country's position in the rankings that consider such an indicator to improve significantly.

However, it should be noted that not all patented inventions immediately find practical applications. Typically, less than 20% of patented inventions materialize into marketed products or processes, and even fewer turn out to be commercial successes. Such a finding is also valid in the case of advanced industrial states.

### 3. Factors influencing the scientific and technical creativity of students

In improving Romania's situation in terms of the number of patent applications submitted annually and, in fact, in increasing the contribution of Romanian citizens to technical progress, including through the number of patent applications registered annually, an important role can be attributed to higher technical education.

It is thus known that, from the total number of patent applications registered annually in Romania, more than 15 % are developed with the contribution of higher technical education [34].

The activities in the direction of promoting the technical creativity of students have revealed the existence of key factors capable of exerting influence on the manifestation of scientific and technical creativity of students [2]. Such factors are, for example, predominantly of biological nature, psychological nature, cognitive-intellectual nature, and socio-economic nature.

It is accepted, in principle, that one important activity in the development of innovative solutions to technical problems is the intensive documentation, to find out the significant results of other developers. But, at the same time, it has been found ineffective activities that in the case of technical problems submitted to be solved by students, some of them were able to arrive at original solutions in a relatively short time, without large documentation, through the original combination and exploitation of the knowledge they had at the time.

It is, also, noted that one of the factors that can affect the process of developing new solutions is the amount of specialized knowledge of the persons involved in such a process.

The volume of professional knowledge can be included in the group of cognitive-intellectual factors, but it can turn, in certain circumstances, into a psychological obstacle to the identification of creative technical solutions, and this could appear when the volume of knowledge seems to be no longer susceptible to development.

To avoid such impediments, it is important to promote the truth that, in general, the knowledge systems are definitively open.

## 4. Conclusions

Examining the evolution of the number of patent applications highlights the growing interest in intensifying the processes of generating patentable technical solutions in different states of the world, especially in the case of developed industrial countries or countries that aim to have rapid industrial development. It was therefore normal to research ways to facilitate the process of identifying new technical solutions.

A regression analysis of the patent development in a few countries, based on statistical data, has been unrolled. The relevant determined regression functions reveal important features of the patent number trendline in correlation with major actions that influenced the socio-economic system development of the considered country.

A key performance indicator defined as the number of patents per one million inhabitants has been introduced to analyze states' efforts in sustaining patent development. This is evidenced by a significant variation of the considered indicator among the chosen group of countries. The result is an expression of a sustaining level of state towards an innovative society.

The key factors influencing the manifestation of scientific and technical creativity of students are predominantly of biological nature, psychological nature, cognitive-intellectual nature, and socio-economic nature.

In perspective, it is considered to identify ways to lead to the involvement in technical creation activities of a larger number of students and specialists with extensive experience in solving technical problems.

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