

Importance Factor - New Patent-Valuation Index

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Abstract

This article demonstrates the usefulness of patent and citation data as a window on the process of technological change and as a powerful tool for research of the economics of innovation. Patent records contain a wealth of information, including the inventor's identity, location, and employer, as well as the technological field of the invention. Patents also contain citation references to previous patents, which allow one to trace links across inventions.

The article presents modified algorithms first constructed by the pioneers in the field, Jaffe & Trajtenberg (2002), that quantify and measure constructed forward and backward patent-importance values based on patent-citation data. The new modified algorithms contribute a more accurate assessment of patent-importance values. The modified algorithms, which express two patent values, "Forward Importance" (FI) and "Backward Importance" (BI), are calculated backward and forward by citation information, based on the first and second-generation patent counts. Furthermore, the fixed lambda factor used in the previous algorithms has been replaced with a new measured lambda algorithm factor. The outcome of these two modified indicators is the Patent Importance Factor (PIF). The quantified, impact index figures express the patent-valuation importance values. The new algorithms particularly enlighten significant changes over time and space in patent-innovation dynamic values and in the known Patent Impact Factor Indicators (PIFI).

Key Words: Patent Importance Factor (PIF), Forward Importance (FI), Backward Importance (BI), Patent Impact Factor Indexes (PIFI).

Introduction

This work will show a way to quantify patent importance with constructed parameters based on original patent variables from the USPTO data base. The patent data include citations to previous patents, opening up the possibility of tracing multiple linkages among inventions, inventors, scientists, firms, locations, etc. In particular, patent citations allow one to study knowledge spillovers between countries and to create indicators that will express the importance of an

individual patent as measured by means of the patent impact factor (PIF). The result will introduce a way of capturing the enormous heterogeneity of the “impact value” of patents. The algorithms for measuring patent importance were first constructed by Jaffe & Trajtenberg (2002), whose algorithms expressed Patent Importance Forward (IMPORTF) and Patent Importance Backward (IMPORTB) to answer some economic questions related to patents. Their comment that different weighted figures in their equations did not change the patent importance forward or the patent importance backward results significantly effectively stimulated the present work. They gave a fixed weight to the first generation of citing and cited patents, and half the weight to the second generation of citing and cited patents. We repeated the experiment, and the results in a few cases (see Appendix 1) showed no difference between forward importance and backward importance results (see Table 1). We came to the conclusion that the fixed weighted factors should be changed. This led us to search for a dynamic weighted factor that would express the importance of citing and cited patents empirically. The main research questions to this end were these: Can we quantify patent- importance values more accurately? Can we generate a dynamic weighted factor to express citing and cited patents?

The first section presents a review of the patent citations literature relating to patent citation and patent-importance methodology, followed by an explanation of the patent importance backward and forward method. Next, we describe the development of the discrimination of the second-generation backward and forward patent-counts method, expanding on the empirical dynamic lambda factor equation and the modified importance backward and forward importance equation. The third section describes the rationale behind the new Patent Importance Factor (PIF). Method and Research Design (Section four) describes how the data was collected, and generated, analyzed, including methodological problems, and the solutions and their effects. The last section pertains to the findings, their presentation and interpretation. Finally the conclusions are summarized, with a discussion of how this knowledge can be used and the shortcomings of the research.

Literature review

The idea of producing a citation index of the patent literature dates back to the early 1950s, as far as formal documentation is concerned, when Seidel (1949) suggested establishing a card file of patent-citation records. Schmookler (1966), Griliches (1987, 1990) and Jorgenson (2005) have used patent citations to measure the economic implications of the connection between R&D and patents in the economy. They used patents and patent statistics as indicators of technological progress. Scherer (1965) explains cross-national differences in innovative activity among the industrialized democracies. In recent years, patent information had limited value in tracing the economic impact of

scientific results, since this data was not linked to economic agents and/ or decisions. Bronwyn (2005), who tried to discover the market value of the patent- citations relationship, explored the usefulness of patent citations as a measure of the “importance” of a firm’s patents, as indicated by the stock-market valuation of the firm’s intangible stock of knowledge. Using patents and citations for 1963–1995, they estimated the concentration-profits relationship by Tobin’s q equations on the ratios of R&D to assets stocks, patents to R&D, and citations to patents. Bronwyn (2004) tried to answer whether evidence of general purpose technologies could be seen in patent data. Using data on three million U.S. patents granted between 1967 and 1999 and the citations they received between 1975 and 2002, the researchers constructed a number of measures of GPTs, including generality, number of citations, and patent-class growth, for patents themselves and for the patents that cite patents. Other researchers looked into spillover and the effect of spatial knowledge on time and space thought-patents and patent citation locally and globally. Spatial patterns of knowledge-related interactions have become a central research issue in the past decade. A series of papers (Jaffe, 1993; Audretsch, 1996; Anselin, 1997; Varga, 2000, 2007), and Keller, 2002), some of them related directly to patents and patent citations, demonstrates that a significant fraction of knowledge flows is bounded spatially.

The reform of the U.S. patent system over the past few decades has caused an explosion in patent applications and grants (Gallini, 2002; Jaffe, 2006). These reforms, which were aimed at strengthening the position of patent holders, were successful in increasing the productivity of research into patents. However, it has also been argued that the quality and importance of patents have decreased and that the patent boom has not generated the economic growth that might have been expected (Jaffe, 2004). This situation has provoked a debate among policy makers and academics over the theoretical and empirical justifications of strengthening patent protection. As long as patents have existed, scholars have debated the optimal length, strength and breadth of protection. A strong rationale for more protection has been formalized in endogenous, innovation-driven growth models, such as those put forth by Romer (1986, 1990), Aghion (1992) and Grossman (1991). In these models, knowledge creation drives economic growth in the long run. Consequently, intellectual property rights (IPR) protection is considered a key institution, allowing inventors to market their inventions and thereby recover their costs. The logic of these models implies that stronger protection stimulates investment in knowledge creation and, consequently, higher growth (Acs, 2008).



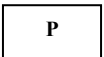

The debate on patents is not new. A number of recent studies have investigated the applicant/examiner issue and the matter of citations appearing in U.S. patents, exploiting the fact that the USPTO has provided information on the source of the citations since 2001 (Alcacer, 2006, 2009; Sampat, 2004; Thompson, 2005; Criscuolo, 2005; and Hegde, 2009). This phenomenon still generates articles that assess differences between the two groups. USPTO and the other patent-data organizations changed policy in the new millennium so that it is now possible to distinguish between applicant citations and examiner citations. This distinction appears in the official patent issued. The complete list of the examiner's citations, as well those of the applicant/inventor, appears in the

paragraph on the reference list. An obvious question was asked by Henderson (1998): Why was it proposed to rescale the citations data rather than simply include the corresponding fixed-effect in whatever regression or other statistical analysis used in the citations? The reason is that such analyses typically examine entities that, in any given year, include patents from many different cohorts as a unit of observation. Hence, the rescaling described here does not correspond to a simple fixed-effects regression. In Bronwyn, Jaffe, & Trajtenberg (2005), patent citations convey information about two major aspects of innovations. The first aspect concerns linkages among inventions, inventors, and assignees along time and space. In particular, patent citations enable a quantitative, detailed study of spillovers along geographical, institutional, and related dimensions. The second is that citations may be used as indicators of the “importance” of individual patents, thus introducing a means of gauging the enormous heterogeneity in the “value” of patents. Bronwyn et al. concentrated on the latter aspect, with only a passing reference to citations as indicators of spillovers when dealing with self-citations. Jaffe & Trajtenberg (2002) expanded innovation in the use of patent-citation analysis through trend analysis, as well as through forward and backward patent citation. They explained the patent-importance value, as well as the patent-demand importance value through patent citation. Their presumption for IMPORTF and IMPORTB was that backward-citation information was the grounding stage for proceeding with further research. Backward-citation information deals with the nature of the research, forward-citation information with the subsequent impact of research outcomes. Researchers have provided evidence, based on descriptive statistics and on multivariate econometrics, that both approaches yield a clear-cut conclusion: citations that originate from inventors/applicants are more concentrated in space than citations that originate from patent examiners.

IMPORTF – IMPORTB (Jaffe & Trajtenberg 2002, p. 58)

Diagram A: Patent with first and second-generation patent citations

(Explanation of symbols:

-  = First-generation forward patent (+g)
-  = Second-generation forward patent (g+1); represents the total number of second-generation citing patents
-  = First-generation backward patent (-g)
-  = Second-generation backward patent (g-1); the total number of second-generation cited patents

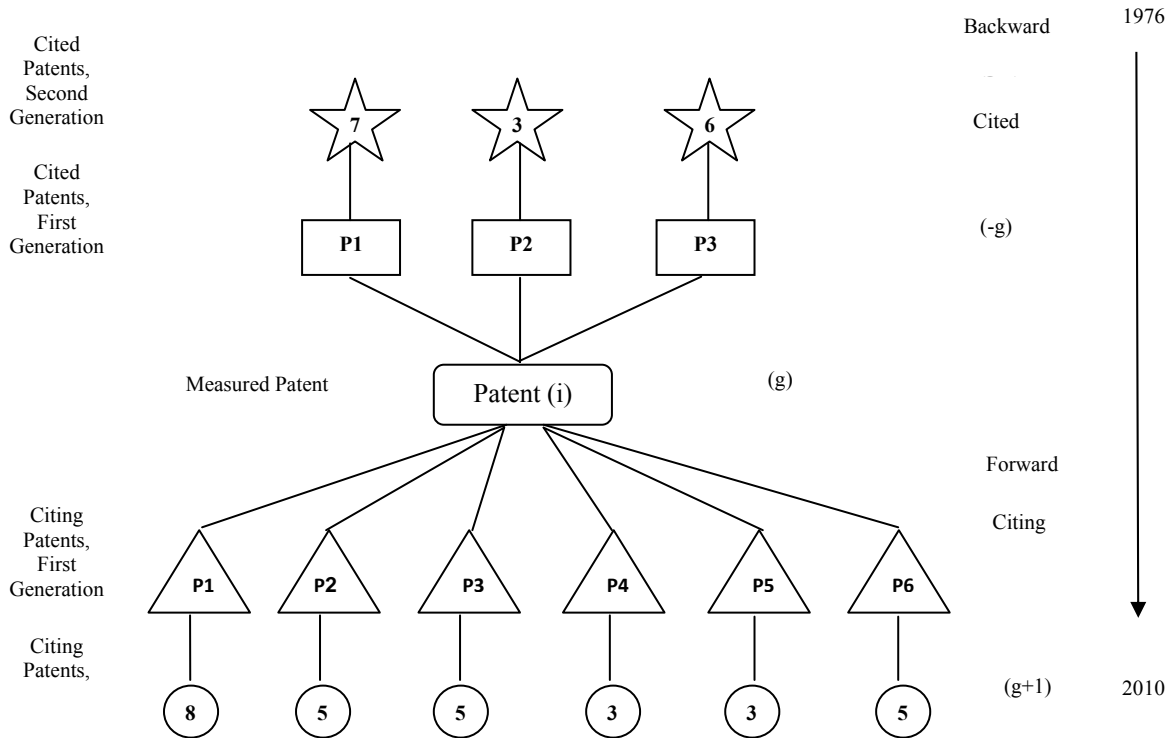
- (g) - Measured-time patent dimension.
- (+g) - First-generation patents, forward dimension.
- (-g) - First-generation patents, backward dimension.
- (g+1) - Second-generation patents in (+g) diminution.

(g-1) - Second-generation patents in (-g) dimension.

NCITING - Number of patents citing the original patent: (+g) (g+1)

NCITED - Number of patents cited by the original patent: (-g) (g-1)

λ - Weighted factor for the first and second-generation patents



The algorithms for measuring patent importance that were first constructed by Jaffe et al. express *IMPORTF* and the *IMPORTB* (see Equations 1,2 below).

"*IMPORTF*"—forward importance—is measured in order to capture the technological impact of an invention as reflected in the number and the importance of its descendents; hence, it corresponds to the most intuitively appealing notion of basic innovations. It captures important determinants of the social returns to innovations: those with many descendents that span a wide range of technical fields are likely to have high social returns.

Eq. (1)

$$IMPORTF(i) = NCITING_i + \lambda \sum_{j=1}^{nciting_i} NCITING_{i+1j}$$

"*IMPORTB*"—backward importance—reflects both the number of subsequent citations and their respective importance (Jaffe & Trajtenberg, 2002, p. 57)

Eq. (2)

$$IMPORTB(i) = NCITED_i + \lambda \sum_{j=1}^{ncited_i} NCITED_{i+1j}$$

In order to better understand the algorithms, we refer to Diagram A, which describes a patent with first and second-generation patent citations.

The Problem with IMPORTB, IMPORTF - Eq. (1), Eq. (2) - algorithms

Lambda is the weighted factor for first and second-generation patents. The lambda figure in algorithms always receives a fixed figure, one for the backward or forward first-generation patent counts and 0.5 for the second-generation patent counts. Jaffe & Trajtenberg (2002, p. 60) posited that a set of different lambdas would not change the results: "different λ 's ($\lambda=0.25$ $\lambda=0.5$ and $\lambda=0.75$) but none of the results appear to 'depend upon.'"

We simulated a few cases (see Appendix 1); the results (see Table 1) show no difference between forward and backward importance in different cases.

The conclusions that may be drawn from the demonstration of the four cases are as follows: IMPORTB= 6 and IMPORTF = 1 were obtained for two different cases (Cases 1 and 2).

IMPORTB = 1 and IMPORTF = 6 were obtained for cases 3 and 4.

Thus, insofar as deriving the importance of forward and backward through their algorithm, they suffer from some inaccuracy.

The reasons we obtained the same results are the following: (a) $\lambda=0.5$, or a fixed weight for all second-generation patents; (b) the results did not distinguish between second-generation patents backward or forward. This led us to search for the dynamic λ factor through the discrimination of second-generation patents and to generate a new empirical dynamic λ factor.

The Empirical Discoveries

In this section, we will describe the preliminary assumptions of the "discrimination concept" of second-generation patent citations that we employed, then the empirical dynamic algorithm for the second-generation lambda factor, followed with the new Importance Factor (IF).

The Assumptions

The following assumptions were made:

- a) Patent citations inform of links between patented innovations. This is compulsory by the patent authorities for the inventor. Citation information about a new invention that is based on previous inventions is presented dynamically on the official forms.
- b) The fact that patent B cites patent A indicates knowledge flowing from A to B and may constitute a "paper trail" for technology/knowledge spillover. Therefore, we accept the assumptions made by Jaffe & Trajtenberg (2002).
- c) For a second-generation patent, citations may indicate its "importance." Citing patents are more important than cited patents. Forward second-generation patents (citing) are more important than backward second-generation patents. Most important is probably the fact that the number of forward-patent citations (FPC) is closely associated with the value of a patent; most of the studies using forward-patent citations agree with this conclusion (see Sapsalis, 2006).

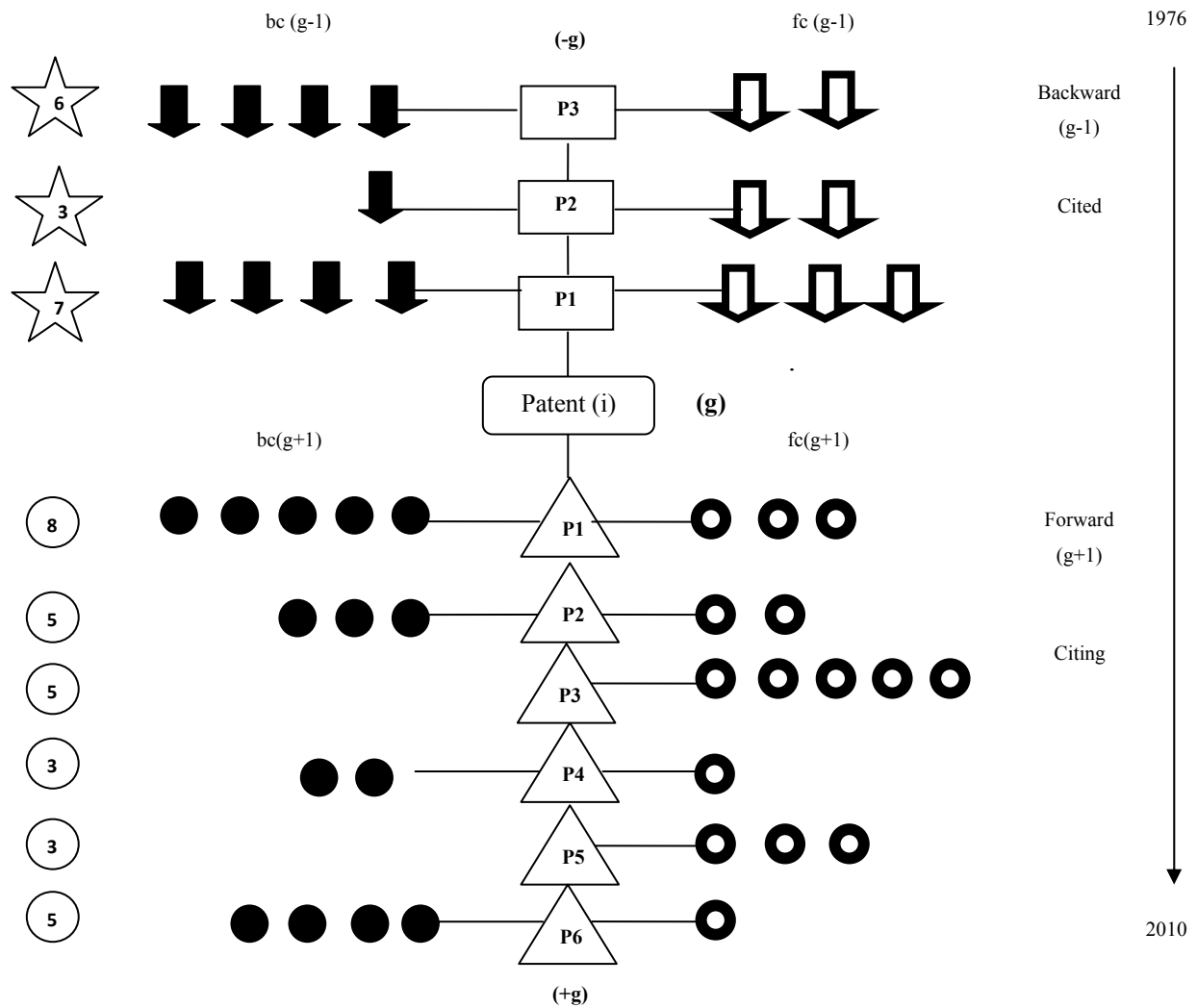
The last three assumptions (c, d, and e) were based on the concept of Journal Impact Factor used in the scientific article. Article A that is cited by fifty other articles will be considered more important than article B that is cited only ten times. We should also take into consideration the time factor.

- d) Backward-citation information is the ground stage from which we can proceed with further research. Backward-citation information will be informative in regard to the nature of the research. These two assumption (f, g) link past information with the future.
- e) Forward-citation information will be informative in regard to the subsequent impact of research outcomes.

Backward and Forward Patent Importance

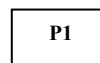
We expanded Diagram A to produce Diagram B by a discrimination of second-generation backward and forward of each patent. Example: P1, backward first generation in Diagram A, has a total of seven second-generation patents. In Diagram B, we have the same seven patents, but four of them were cited and three were citing.

Diagram B

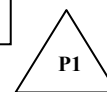


Six groups of patents were obtained (see below). These groups will constitute the base for generating the calculations and establishing our hypotheses.

Bc (-g) - Backward citation, first-generation patents



fc (g-1) - Forward citation, first-generation patents



bc (g-1) - Backward citation, second-generation patents (Backward - Cited)



Fc (+g) - Forward citation, second-generation patents (Backward - Citing)



fc (g+1) - Forward citation, second-generation patents (Forward - Citing)



bc (g+1) - Backward citation, second-generation patents (Forward - Cited)



The discrimination of second-generation patents (Diagram B) leads to a better resolution of the different second-generation groups of patents. We generated six patent groups to express patent importance, compared to Jaffe & Trajtenberg's (2002) results. The six groups were generated, based on the assumptions that (d) citing patents are more important than cited patents and that (e)

forward second-generation patents (citing) are more important than backward second-generation patents. After having distinguished between the forward and backward first and second-generation patent citations and after discriminating between the number of forward and backward first and second-generation patent citations, we can generate the dynamic factor for every patent.

Empirical Algorithm for the Dynamic λ Factor

Taking into consideration the different assumptions, we arrived at an empirical algorithm for the second-generation forward and backward citation patents.

The backward dynamic factor is equals to the forward second-generation group of patents divided by the sum of the forward and backward second generation plus one. We decided to add one to avoid infinity results.

The empirical dynamic lambda factors are as follows:

Eq. (3)

$$\lambda_{DB(P1)} = \left(\frac{fc_{(g-1)(P1)}}{(1 + fc_{(g-1)(P1)} + bc_{(g-1)(P1)})} \right)$$

Where:

$\lambda_{DB(P1)} = \lambda$ *dynamic backward second generation*

$fc_{(g-1)(P1)} =$ *Forward second generation (citing)*

$bc_{(g-1)(P1)} =$ *Backward second generation (cited)*

We did the same for the forward second-generation patents. The forward dynamic factor is equals to the forward second-generation group of patents divided by the sum of the forward and backward second generation plus one. (See Eq. 4.)

Eq. (4)

$$\lambda_{DF(P1)} = \left(\frac{fc_{(g+1)(P1)}}{(1 + fc_{(g+1)(P1)} + bc_{(g+1)(P1)})} \right)$$

Where:

$\lambda_{DF(P1)} = \lambda$ *dynamic forward second generation*

$fc_{(g+1)(P1)} =$ *Forward second generation (citing)*

$bc_{(g+1)(P1)} =$ *Backward second generation (cited)*

We generated the dynamic λ factor through a discrimination of the second-generation patents and the new empirical λ calculation. This will lead to a better resolution of patent importance.

When there are differences in the second-generation citation patents, the dynamic patent-citation situation has to be taken into consideration. Furthermore, the exact date of the calculations must always be known because of the changes in time and citations over time.

We will now discuss three cases that will present the differences. Comparisons will be made between FIP and IMPORTF, BIP and IMPORTF, and with PIF.

The Modified Algorithm - Backward Importance (BI)

We used the basic Eq. (1) and substituted the dynamic Eq. (3) for the fixed lambda factor of 0.5. The first-generation patents received a lambda equal to one, and the second-generation patents received the dynamic lambda described in Eq. (3)

Backward Importance equals the sum of first-generation backward patents plus the sum of the second-generation forward group of patents to the power of two, divided by the sum of the second forward plus second backward plus one. (See Eq. 5.)

Eq. (5)

$$BI(i) = \sum_{P=1}^{N(-g)} (Bc_{(-g)}) + \sum_{P=1}^{N(g-1)} \left(\frac{fc_{(g-1)}^2}{(1 + fc_{(g-1)} + bc_{(g-1)})} \right)$$

Where:

$BI(i)$ = Backward Importance

$Bc_{(-g)}$ = Backward firstgeneration patents

$fc_{(g-1)}$ = Forward second generation (citing)

$bc_{(g-1)}$ = Backward second generation (cited)

The Modified Algorithm - Forward Importance (FI)

We used the basic Eq. (2) and substituted the dynamic Eq. (4) for the fixed lambda factor of 0.5.

The first-generation patents received a lambda equal to one, and the second-generation patents received the dynamic lambda as described in Eq. (4).

Forward Importance equals the sum of first-generation forward patents plus the sum of the second-generation forward group of patents to the power of two, divided by the sum of second forward plus second backward plus one. (See Eq. 6.)

Eq. (6)

$$FI(i) = \sum_{P=1}^{N(+g)} (Fc_{(+g)}) + \sum_{P=1}^{N(g+1)} \left(\frac{fc_{(g+1)}^2}{(1 + fc_{(g+1)} + bc_{(g+1)})} \right)$$

Where:

$FI(i)$ = Forward Importance

$Fc_{(+g)}$ = Forward firstgeneration patents

$fc_{(g+1)}$ = Forward second generation (citing)

$bc_{(g+1)}$ = Backward second generation (cited)

Patent Importance Factor (PIF)

Jaffe & Trajtenberg's (2002) assumption for IMPORTF and IMPORTB was that backward-citation information, which deals with the nature of the research, provided the grounding stage for proceeding with further research. The PIF rationale was based on physics. In mechanics, a simple machine is a mechanical device that changes the direction or magnitude of a force (Akshoy, 2005). In general, it can be defined as the simplest mechanism that makes use of mechanical advantage, or leverage, to multiply force. According to Asimov (1988), mechanical advantage (MA) is the factor by which a mechanism multiplies the force or torque applied to it. Generally, mechanical advantage is defined as the ratio of the output to the input force (Ostdiek, 2005).

Mechanical Advantage = (Output Force)/(Input Force) In electronics, the gain of an amplifier is the ratio of output to input power, or amplitude, and is usually measured in decibels. (When measured in decibels, it is logarithmically related to the power ratio:

Gain (dB) = (Power Output)/(Power Input)).

- a) Backward-citation information is the ground stage from which we can proceed with further research.
- b) Backward-citation information will be informative in regard to the nature of the research.
- c) Forward-citation information will be informative in regard to the subsequent impact of research outcomes.

Based on the assumptions (a) that in physics the gain in electronics and mechanical advantage are obtained when we calculate the ratio between the output and the input; (b) that the assumption that backward-citation information is the ground stage from which to proceed with further research; (c) that BI (i) represents the "input" and that forward-citation information will inform about the subsequent impact of the research outcomes; and (d) PIF(i) represents the "output," then

PIF equals the ratio of FI (i) to BI (i).

We added 1 to the numerator and +1 to the denominator to avoid zero and affinity results.

Thus:

Eq. (7)

$$PIF(i) = (1 + (FI(i))) / (1 + (BI(i)))$$

and

Eq. (8)

$$PIF(i) = \frac{1 + \sum_{P=1}^{N(+g)} (Fc_{(+g)}) + \sum_{P=1}^{N(g+1)} \left(\frac{fc_{(g+1)}^2}{(1 + fc_{(g+1)} + bc_{(g+1)})} \right)}{1 + \sum_{P=1}^{N(-g)} (Bc_{(-g)}) + \sum_{P=1}^{N(g-1)} \left(\frac{fc_{(g-1)}^2}{(1 + fc_{(g-1)} + bc_{(g-1)})} \right)}$$

Method and Research Design

Patents were collected from the USPTO data base.

The "Patent iNSIGHT Pro" software program, an advanced patent-research and mapping platform, from Gridlogics Technologies Pvt. Ltd., India, was used for the analysis.

Original Patent Variables

1. Patent number
2. Dates: (a) Published dates, (b) Issued dates, c) Priority dates
3. Number of forward-citation patents: First generation - Fc(+g)
4. Number of backward-citation patents: First generation - Bc(-g)
5. Number of forward-second generation patents: Forward citation - fc(+g+1)
6. Number of backward-second generation patents: Forward citation - bc(+g+1)
7. Number of forward second-generation patents: Backward citation - fc(-g-1)
8. Number of backward second-generation patents: Backward citation - bc(-g-1)

Constructed patent parameters

1. FI (i) - Forward Importance.
2. BI (i) - Backward Importance.
3. IF (i) - Importance Factor.

Results

Table 1: Problem with IMPORTB and IMPORTF

Eq. (1) and Eq. (2) Algorithms

	Case number	IMPORTB	IMPORTF
See Appendix 1	Case 1	6.00	1.00
See Appendix 1	Case 2	6.00	1.00
See Appendix 1	Case 3	1.00	6.00
See Appendix 1	Case 4	1.00	6.00

Table 2: Comparison of IMPORTB and IMPORTF with BI, FI, and PIF

	Case Number	IMPORTB	BI	IMPORTF	FI	PIF	PIFyt(*)
See Appendix 1	Case 1	6.00	1.00	1.00	1.00	1.00	0.16
See Appendix 1	Case 2	6.00	10.09	1.00	1.00	0.09	0.16
See Appendix 1	Case 3	1.00	1.00	6.00	1.00	1.00	6.00
See Appendix 1	Case 4	1.00	1.00	6.00	10.09	10.09	6.00

(*)In order to compare PIF with the IMPORTF- MPORTB ratio, we calculated PIF (Jaffe-Trajtenberg) in the following way:

Eq. (9)

$$PIF(y - t) = \text{IMPORTF} : \text{IMPORTB} = \frac{1 + (\text{IMPORTF}(i))}{1 + (\text{IMPORTB}(i))}$$

Table 3: Diagram C, US 7,569,637 and US 4,459,085 results

	Case number	IMPORTB	BI	IMPORTF	FI	PIF	PIFyt
Diagram C	Case 5	11.00	5.69	20.50	12.43	2.00	1.79
US 7,569,637	Case 6	49.00	71.1	44.00	1.00	0.02	0.90
US 4,459,085	Case 7	17.50	6.13	135.50	42.83	6.14	7.37

Discussion

Results - We simulated four cases to prove that there is no sensitivity between forward and backward second-generation patents. The difference between Cases 1 and 2 is that in Case 1, the ten patents in the backward second generation are cited; and in Case 2, the ten patents are citing. We performed the same simulation in Cases 3 and 4, this time in the forward side.

Table 1- Results show no sensitivity between the private cases (1, 2): $IMPORTB=6$ and $IMPORTF=1$ produced the same results for different citations. We obtained the same results for Cases 3 and 4, when $IMPORTB=1$ and $IMPORTF=6$. (See Appendix 1.)

Table 2 – This table shows the results of the comparison between $IMPORTB$ and $IMPORTF$, on the one hand, and BI , FI , and PI , on the other. We used the same four cases to show that the new modified BI and FI algorithms do exhibit sensitivity between different cases. Results show that BI receives different figures: $BI(case1) = 1.00$; $BI(case2) = 10.09$; $BI(case3) = 1.00$, and $BI(case4) = 1.00$; and that FI also receives different figures: $FI(case1) = 1.00$, $FI(case2) = 1.00$, $FI(case3) = 1.00$, and $FI(case4) = 10.09$.

When one compares PIF with PIF_{yt} in Table 2, the results show sensitivity with the PIF results. The reason for these differences is that the dynamic factor is used for the second-generation patents - forward and backward. PIF_{yt} show no differences.

Table 3 – This table presents three different cases. Case 5 is Diagram C. Case 6 represents a young patent that was published on August 4, 2009, with a small number of citations. Case 7 is a relatively old patent with more citations. In this manner, we covered the complete range of patent citations and the different results of PIF , IF , and IB from $IMPORTF$ and $IMPORTB$.

In Case 5, we can see that the results have no proportion when $IMPORTB=11.00$ than the modified algorithm $BI= 5.69$; the same but opposite proportion occurs with $IMPORTF=20.50$ and $FI=12.43$. PIF and PIF_{yt} show different results, as well.

The same may be said for Case 6, Patent no. 7569637. Since this patent is from August 4, 2009, it is natural that other patents had not yet cited it; thus, we have only five cited patents.

PIF results magnify the differences between the two methods of calculation; in this case, $PIF=0.02$ compares with $PIF_{yt}=0.90$, resulting in large differences in BI and FI . Case 7, Patent no. 4,459,085. This case presents a situation in which a patent has forward and backward citations. The differences are very significant with the forward results: $IMPORTF 135.5$ compared with $FIP 42.83$ (Table 3). These differences are magnified because of the discrimination of forward and backward second-generation patents and the dynamic λ factor. We can see that there are no significant differences between $PIF= 6.14$ and $PIF_{yt}=7.37$.

The new PIF (i) algorithms take into consideration four main elements:

- A) The assumptions (listed below).
- B) The discrimination of second-generation patents.

C) The dynamic λ factor.

D) PIF equals the "output" to "input" ratio.

The assumptions of this research are the following:

- a) Citing patents are more important than cited patents.
- b) Forward second-generation patents (citing) are more important than backward second-generation patents.
- c) Backward citation information is the ground stage from which we can proceed with further research.
- d) Backward-citation information will be informative in regard to the nature of the research.
- e) Forward-citation information will be informative in regard to the subsequent impact of research outcomes.

The dynamic λ factor can be generated through a discrimination of second-generation patents, leading to a better resolution of the different groups of patents. Six groups were generated:

Bc (g) - Backward citation, first-generation patents.

fc (-g-1) - Forward citation, second-generation patents. (Backward-Cited)

bc (-g-1) - Backward citation, second-generation patents. (Backward-Cited)

Fc (+g) - Forward citation, first-generation patents.

fc (+g+1) - Forward citation, second-generation patents. (Forward-Citing)

bc (+g+1) - Backward citation, second-generation patents. (Forward-Citing)

Based on the assumptions that (a) citing patents are more important than cited patents and (b) forward second-generation patents (citing) are more important than backward second-generation patents, and after having distinguished between the forward and backward first and second-generation patent citations and discriminated between the number of forward and backward first and second-generation patent citations, we can then generate the dynamic factor for every patent.

The dynamic λ factors are as follows:

Eq. (10)

$$\text{Dynamic } \lambda \text{ factor, backward patent} = \left(\frac{fc_{(-g-1)}}{(1 + fc_{(-g-1)} + bc_{(-g-1)})} \right)$$

Eq. (11)

$$\text{Dynamic } \lambda \text{ factor, forward patent} = \left(\frac{fc_{(+g+1)}}{(1 + fc_{(+g+1)} + bc_{(+g+1)})} \right)$$

When there are differences in the second-generation citation patents, the dynamic patent-citation situation has to be taken into consideration. Furthermore, the exact date of the calculations must always be known because of the time change and citations over time.

We will now discuss three cases that present these differences. Comparisons will be made between FIP and IMPORTF, and between BIP and IMPORTF and PIF.

Time scale - Time scale refers to the time from a measured patent (i) to the last backward second-generation; also, to the time of the last forward second-generation of the measured patent. This time scale should be looked at carefully because of the different conclusions that can be made regarding some of the patent-importance figures.

Example A: A measured patent for which the application date is 2008.

The number of first and second-generation patents is zero. Thus, $PIF = 0$.

Example B: A measured patent for which the publication date is 1995.

The number of first and second-generation patents is zero. Thus, $PIF = 0$.

In example B, it may be assumed the patent is not important, because the PIF is zero and the measured patent-publication date is fifteen years old. In example A, the fact that the measured patent is only two years old should tell us that there is still time to analyze that patent further in the coming years. We plan to examine the time factor in future research.

Time Line - Time line is another important issue for PIF and BIP. The patent data bases have three major dates and three time lines for counting the first and second patent generations: the application date, the publication date, and the priority date. These are defined as follows:

Application date - the date on which a patent was applied for.

Publication date - the date on which a patent was granted; this is often several years after the application and priority dates.

Priority date - the date that, for patent-law purposes, is assumed to be the date of invention; this is often the same as the application date, but it may be up to one year earlier owing to foreign patent applications, which may serve as proof of date of invention. It is recommended that the publication-date time line be used to calculate patent importance. When only parts of the patent-impact factor are measured, there is need to be careful with the final conclusion. The complete picture of the measured patents or the single patent must be taken into consideration by reviewing the patent.

Conclusions

The research results add a new index with which the research community can better evaluate patents. This tool offers a way to quantify innovation and spillovers over time through patents, thereby providing one more tool to analyze patents along with other econometric factors.

The recommended algorithm to measure PIF is the ratio between PIF and BIP.

The following algorithm measures the patent Impact Factor (IF):

Eq. (12)

$$\text{PIF}(i) = \frac{1 + \sum_{P=1}^{N(+g)} (\text{FC}_{(+g)}) + \sum_{P=1}^{N(+g+1)} \left(\frac{\text{fc}_{(+g+1)}^2}{(1 + \text{fc}_{(+g+1)} + \text{bc}_{(+g+1)})} \right)}{1 + \sum_{P=1}^{N(-g)} (\text{BC}_{(-g)}) + \sum_{P=1}^{N(-g)-1} \left(\frac{\text{fc}_{(-g)-1}^2}{(1 + \text{fc}_{(-g)-1} + \text{bc}_{(-g)-1})} \right)}$$

In the event that no second-generation patent citation exists, then only the ratio of the first generations is obtained. It is recommended, as well, that the first-generation ratio be checked if time is in short demand. Time scale (TS) and Time line (TL) need to be taken in to consideration, too. Another recommendation is to consider the results of Forward importance (FI) and Backward importance (BI) in order better to understand and explain PIF results.

Research Limitations

The largest international patent offices are the EPO, the JPO, and the USPTO. Together, these three offices are responsible for processing some 90% of all patent subject matter across the globe. The significant innovative patents will always appear in the USPTO data base. Although our research used only this data base, it may suffer from some distortion of the results.

The biggest change in patent-citation policy occurred in 2001, when examiners had to accept the inventor's citation. The nature of an examiner's patent REF makes an important contribution to the effectiveness of the citation index of the patent literature. REF is now generated as part of the search for prior art, which can be grounds for disallowing a claim, restricting the scope of the application, or supporting a legal point (within the patent application). Prior to 2001, the USPTO ignored patent citations by the inventor. This change, on the other hand, can somewhat distort a patent's importance value. One way to overcome this distortion is by counting citations in the prior art section before 2001 and adding them for more accurate calculations. There are some limitations to the use of patent data, the most glaring being the fact that not all inventions are patented. Furthermore, not all inventions meet the patentability criteria set by the USPTO: the invention has to be novel, non-trivial, and to have commercial application. As a result, as mentioned, the present work may suffer from some distortion of the results.

Future Research

Many empirical papers close with interpretive cautions and calls for further research. This paper is no exception, but the caution and the call are stronger here than usual. For reasons of limited time and computing power, we were unable to explore the validity and use of the measures we constructed as much as we would have liked, and therefore we encourage further work in this area. We believe that there is need to expand the indicators in order to help compile PIFI. Accordingly, the influence of "time scale," "originality," "generality," and other "patent indicators" of PIFI should be investigated.

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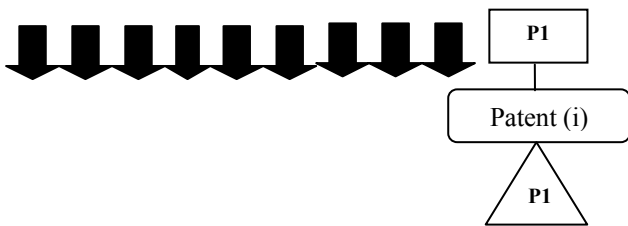
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Appendix 1

Case 1

The figures for this case are as follows:

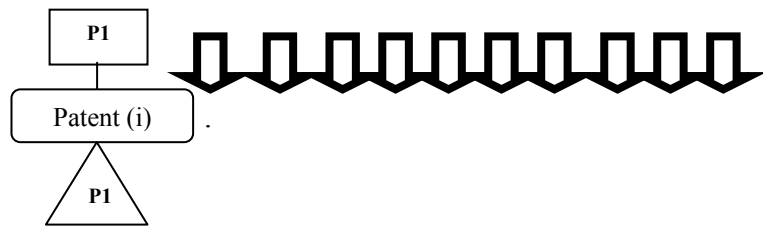
- Bc (-g) – Backward citation, first-generation patents =1
- fc (g-1) – Forward citation, second-generation patents = 0
- bc (g-1) – Backward citation, second-generation patents = 10
- Fc (g) – Forward citation, first-generation patents= 1
- fc (g+1) – Forward citation, second-generation patents= 0
- bc (g+1) – Backward citation, second-generation patents= 0



Case 2

The figures are as follows:

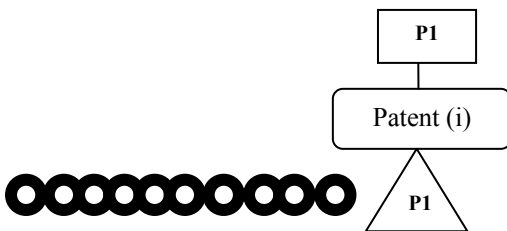
- Bc (-g) - Backward citation, first-generation patents =1
- fc (g-1) - Forward citation, second-generation patents = 10
- bc (g-1) - Backward citation, second-generation patents = 0
- Fc (g) - Forward citation, first-generation patents= 1
- fc (g+1) - Forward citation, second-generation patents= 0
- bc (g+1) - Backward citation, second-generation patents= 0



Case 3

For this case, $fc(g-1) = 10$ and $bc(g-1) = 0$, the patent figures are these:

- Bc (-g) – Backward citation, first-generation patents =1
- fc (g-1) – Forward citation, second-generation patents =0
- bc (g-1) – Backward citation, second-generation patents = 0
- Fc (g) – Forward citation, first-generation patents= 1
- fc (g+1) – Forward citation, second-generation patents= 0
- bc (g+1) – Backward citation, second-generation patents= 10



Case 4

For this last case, $fc(g-1) = 10$ and $bc(g-1) = 0$, the patent figures are these:

- Bc (-g) – Backward citation, first-generation patents =1
- fc (g-1) – Forward citation, second-generation patents =0
- bc (g-1) – Backward citation, second-generation patents = 0
- Fc (g) – Forward citation, first-generation patents= 1
- fc (g+1) – Forward citation, second-generation patents= 10
- bc (g+1) – Backward citation, second-generation patents= 0

