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The influence of the amount of inventors on patent quality

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Introduction

When measuring patent quality, different indicators are taken into account. An indicator is measurable information that can be found in the bibliographic data of a patent directly or in combination with other, non-patent bibliographic data (hybrid indicator)[1]. In literature some patent quality-related indicators have been introduced, i.e. the amount of foreign patents citing a certain patent (forward citations or "cited-by"), the family size, the amount of oppositions[2], the duration from application to grant, the backward citation or the amount of claims[3][4].
All these indicators are taking external facts into account that become measurable after a patent has been filed and published. The core influence factor on a patent – the inventor – is investigated quite rarely. Within regional studies, by example, the inventive productivity was measured by counting number and quality of inventions by a set of frequent applying inventors[5]. Also a kind of "inventor-quality" has been focused with respect to the scientific degree of inventors by measuring the non-patent publications of an inventor in order to derive a patent quality by highly scientifically active inventors[6]. Also the direct environment and innovative community inventors are in, was investigated [7].
Inventions are done by one or a group of inventors. The main question for this study was "how does the size of the inventor- team affect the qualitatively output of the invention?" – there are different theses that should be investigated, proved or disproved by doing this study.
1st single inventor-inventions are side inventions
2nd the more inventors are involved with an invention the higher the R&D Budget, the higher the quality or
3rd the bigger the size of inventor team, the more inefficient the lower the patent quality
4th effective inventor-teams have a typical size.

Methodology

Within the study the size of inventor teams was measured statistically and correlated with other patent quality indicators. Example: How often were patents cited, that were invented by one inventor or a certain set of inventors. By correlating the inventor-team size with indicators that are known from literature to be value relevant, it is possible to derive an additional indicator by the inventor-team size. So the inventor-team size was correlated first to the family size second to the forward citations[8] and third to a combined set of quality indicators, in

[1] Levitt, J. M., & Thelwall M. (2011). A combined bibliometric indicator to predict article impact. Information Processing & Management. (47.2), 300–308..
[2] Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. Research policy : a journal devoted to research policy, research management and planning, 32(8), 1343–1363.
[3] Lanjouw, J. O., & Schankerman, M. (1999). The quality of ideas: Measuring innovation with multiple indicators. NBER working paper. Cambridge [US]: National Bureau of Economic Research.
[4] Squicciarini, M., Dernis, H., & Criscuolo, C. (2013). Measuring patent quality: Indicators of technological and economic value. OECD science, technology and industry working papers: 2013/03. Paris: OECD.
[5] Schettino, F., Sterlacchini, A., & Venturini, F. (2013). Inventive productivity and patent quality: Evidence from Italian inventors. Journal of policy modeling : JPMOD ; a social science forum of world issues, 35(6), 1043–1056.
[6] Breschi, S., & Catalini, C. (2010). Tracing the links between science and technology: An exploratory analysis of scientists' and inventors' networks. Research policy : policy and management studies of science, technology and innovation, 39(1), 14–26.
[7] Giuri, P., Mariani, M., Brusoni, S., Crespi, G., & Francoz, D. (2007). Inventors and invention processes in Europe: Results from the PatVal-EU survey. Research policy : a journal devoted to research policy, research management and planning, 36(8), 1107–1127.
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order to verify that a certain size of inventor groups is not only correlated to just one single phenomenon (i.e. the more inventors, the bigger the family) but with a higher patent quality in general.

Within the study different distributions were analysed in order to determine representative or statistical relevant groups. Then the different groups were compared in order to see differences. Example, the top 10% were compared to the worst 10%, the top 20% to the worst 20%. By comparing different groups, it is possible to see if a certain significance is given and if, what determines the significance.

Additionally, deviations were done in order to better identify differences that may be difficult to see in a direct comparison of groups.

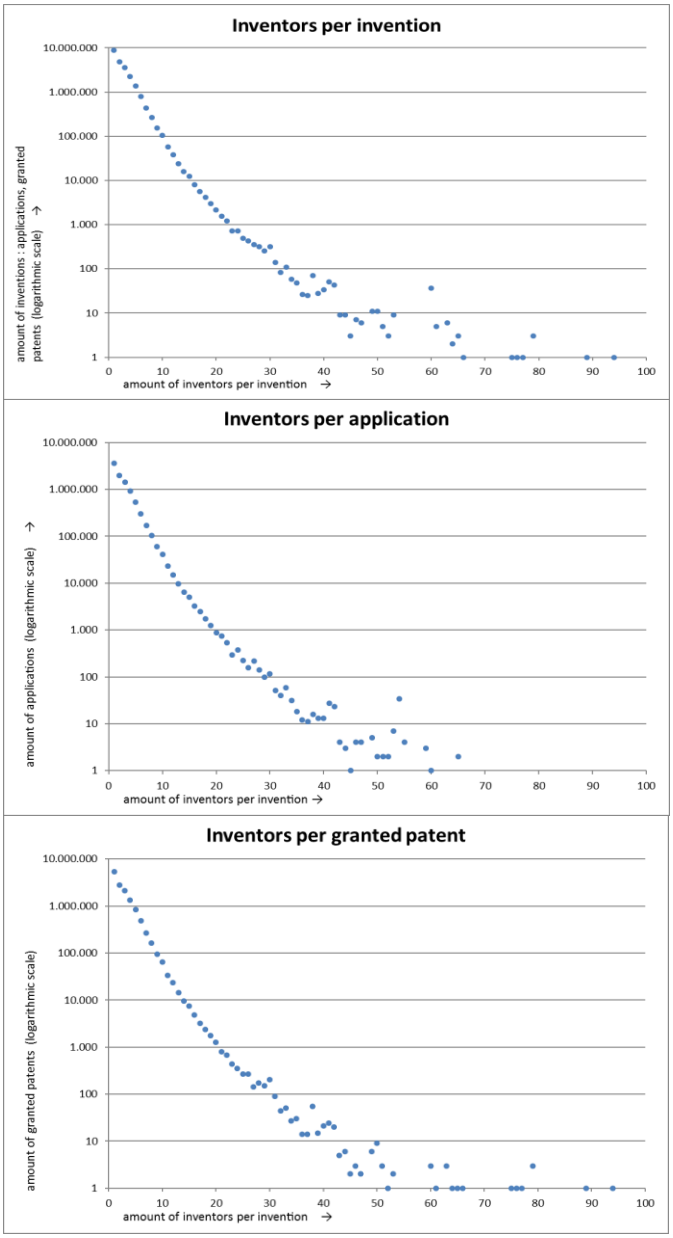
Within the study over 25 million worldwide alive patents have been considered.

Results

a) General distribution inventors per invention

In order to make the distribution seeable within a graphical representation, a logarithmic scale had to be used. Also the distribution was done based on all inventions (applications, granted patents, utility models), only applications and only granted patents. In all different groups the image is similar. Especially within the group of just few inventors the image seems to be more or less identical – there seems to be no significant difference between applications and granted patents: small groups of inventors dominate the picture: The absolutely biggest class of patents is applied by and granted for single-inventor-inventions (38,97% of all inventions, 38,98% of all applications, 38,96% of all granted patents). In terms of the distribution of applications vs. granted patents there is no significant difference in the general picture and shares.

The statistical relevant size is below 20 inventors: 99,97% of all inventions, 99,96% of all applications, 99,97% of all granted patents have 20 or less inventors.



Picture 1:
Distribution of inventors per all inventions, per applications and per granted patents (upper, middle, lower diagram)

b) Distribution of patent family size

Within the following analysis, the family size was monitored in order to see if there is some significance in its distribution. Also here a logarithmic scale had to be used since the biggest group is the smallest patent family with only one member (60,49% all inventions, 56,39 applications and 63,39% granted patents).

More interesting in terms of significance is the fact that there are 3 groups seeable: a group with

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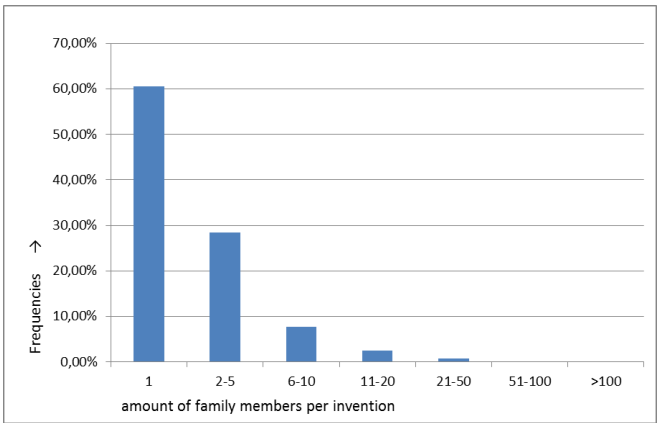
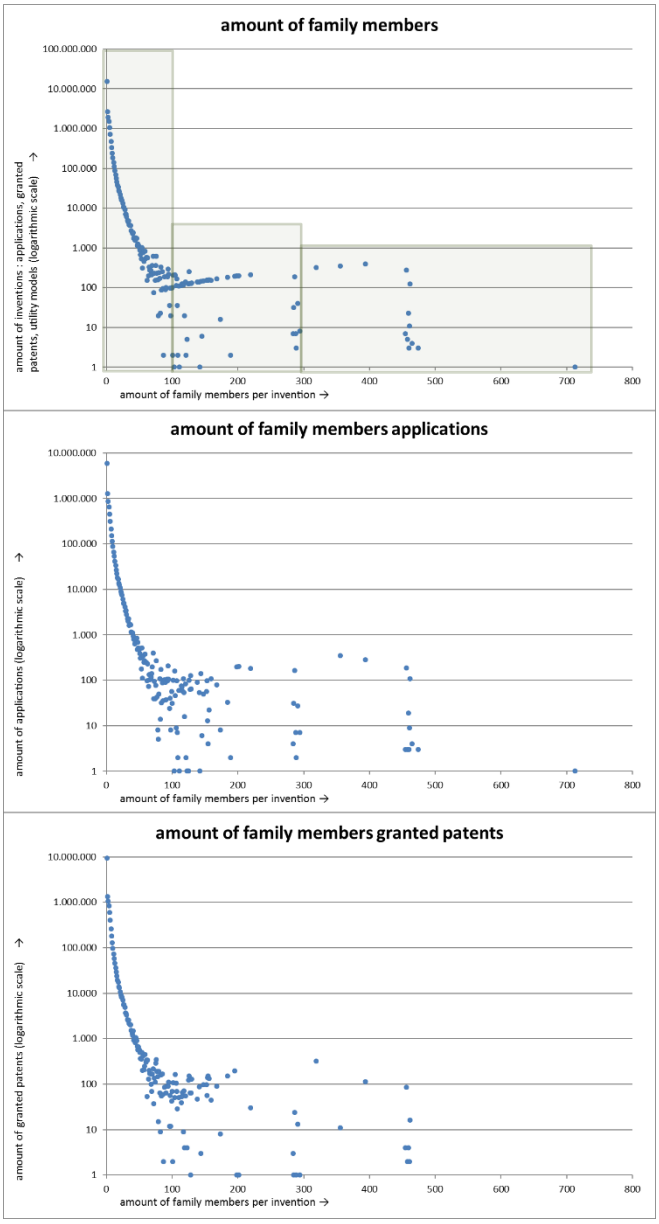
less than 100 family members (99,97% of all inventions, 99,96% applications, 99,98% granted patents),a second group with 101-300 family members (0,02% of all inventions, 0,03% applications, 0,019% granted patents) and a third group with more than 300 family members (0,01% of all inventions, 0,01% applications, 0,004% granted patents).

So it is making sense to build groups that are having different sizes in the amount of family members in order to improve statistical relevance when comparing groups.



Picture 3:
Statistical relevant groups of the family members per invention



Picture 2:
Distribution of inventors per all inventions, per applications and per granted patents (upper, middle, lower diagram), in logarithmic scale

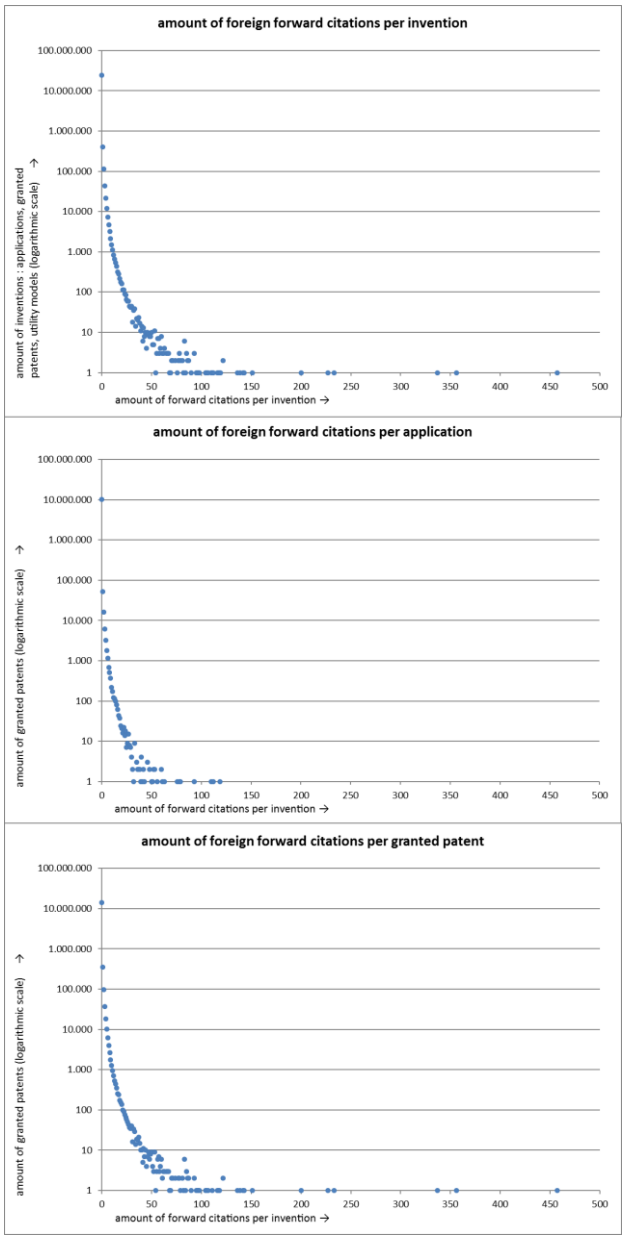
Results

c) Distribution of cited-by

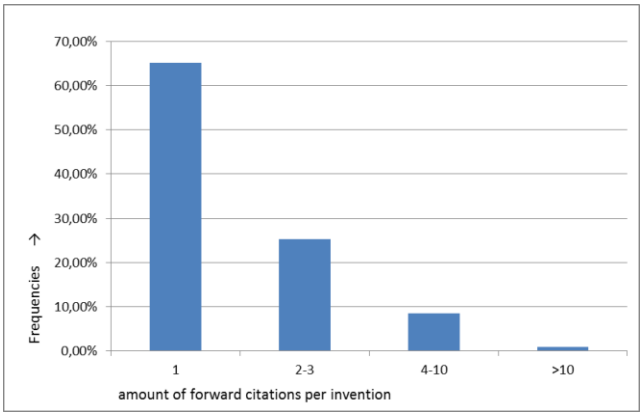
The cited-by indicator is one of the most important quality indicators known from literature. This is why this indicator was also taken into account for the following inventor analysis. First there was also the general distribution analyzed in order to find out if there are certain statistical obvious cases or groupings.

The distribution of the foreign cited-bys - these are all forward citations that were done by assignees that are different to the assignee of the cited patent – has some significances: even though the scale is logarithmic, the distribution is difficult to display: 97,52% of all patents have never been cited (by foreign assignees). For applications, even 99,19% were never cited. So only a very few portion of patents get cited. There for it is useful to group into statistical relevant groups that can be better compared statistically[9]. Among those 2,48% cited patents 65,2% are cited once, 25,36% were cited 2-3 times, 8,49% were cited 4-10 times and 0,95% were cited more than 10 times.

[9]Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. The Rand journal of economics, 36(1), 16–38.



Picture 4:
Distribution of cited-by per all inventions, per applications and per granted patents (upper, middle, lower diagram) in logarithmic scale

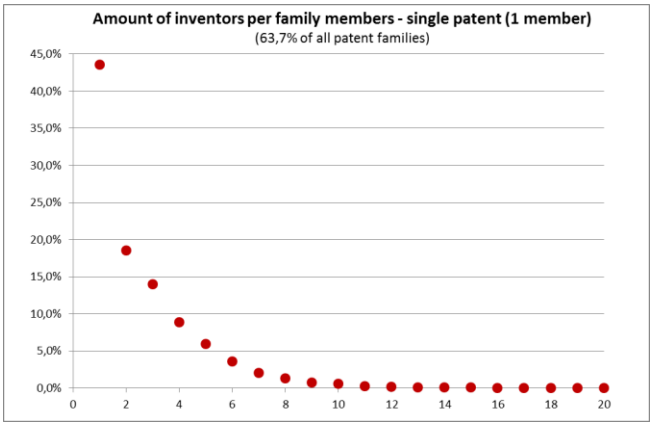


Picture 5:
Statistical relevant groups of the forward cited patents per invention

d) Inventors per family sizes

For the key analysis there have been done different requests in order to see the amount of inventors that are correlated with the family sizes and the forward citations. According to the statistical relevant groups (see picture 3), seven different distributions were done.

For the biggest group - the one-family-member patents - the picture is similar to the total inventor distribution: In this biggest group the one-inventor-patents have the highest occurrence. Nearly half of all these single patents (63,7% of all families) have only one inventor (43,6%), the second biggest occurrence with 2 inventors is less than half in size (18,5%), the decrease of frequencies for all the following inventor sizes is disproportionately. It looks like a well steady function.



Picture 6:
Inventor-frequencies in the smallest group of alive patents (applications and granted patents) containing only 1 family member. Most patents have only 1 inventor

The smaller the groups become in size (the bigger the family sizes become according to the groupings recognizable in picture 3), the smaller the one-inventor-patent group becomes. The other groups of inventors have also small changes in size but not to a significant extent. It can be seen that the weight of the distribution moves to the right, towards bigger inventor-amounts.

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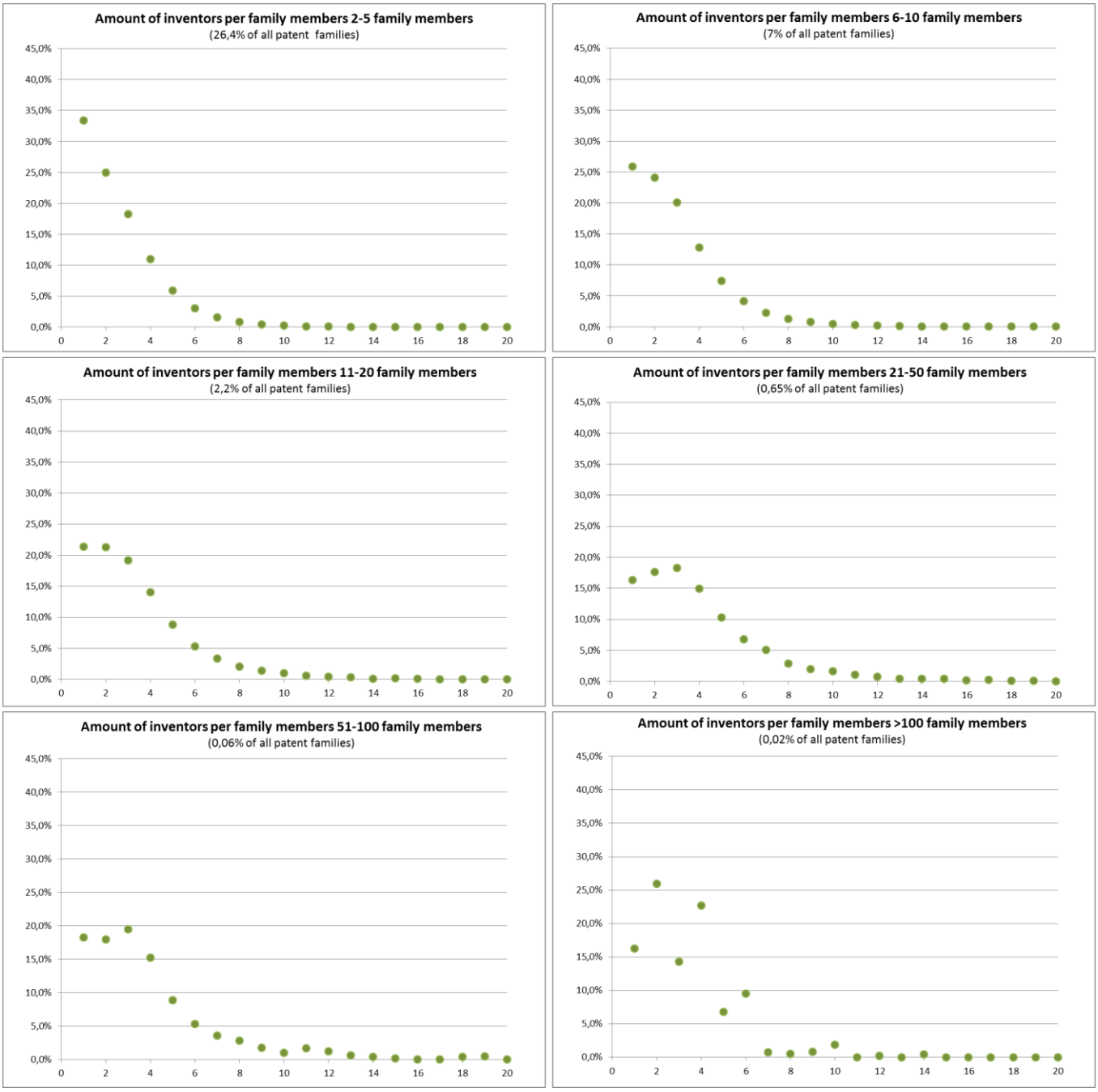

Picture 7:
Distribution of the inventor-group-size frequencies correlated with the different family sizes. The bigger the family sizes, the more relevant become inventor-team-sizes of 2 - 4 inventors (biggest groups) and the less relevant become the one-inventor patents

For big sized families (21-50 family members and 51-100 family members) the apex of the distribution is 3 inventors. That means that the one-inventor patents have decreased dramatically in size also the 2-inventor group has decreased in size to some extent. For the smallest group of families containing more than 100 family members (these are only 0,02% of all families), the distribution seems not to follow a steady function anymore, here the frequencies between the different inventor group-sizes have the strongest variation (picture 7 bottom right) Considering the fact that the biggest frequency decreases most while other frequencies rise, it might be helpful to see the trend. There for the change of frequencies was analysed by comparing the different groups with the single-patent group.

Picture 8:
Changes in frequencies of the different family size groups in comparison to the single patents (one family member).

In all direct comparisons, the one-inventor group decreases as long as the family is bigger than one patent. The strongest decrease in size in the one-inventor group is observed in the biggest family group of >100 family members. Here the decrease is -27,31%. In the group of 21-50 family members the decrease is almost equal with -27,30%. It becomes obvious that the inventor size is correlated to the family size: The bigger the families, the less frequent one-inventor patents are. Also, the positive trend is recognizable in the bigger inventor-group classes: especially the group of 2-8 inventors have increased in bigger families (bigger than 10 family members).

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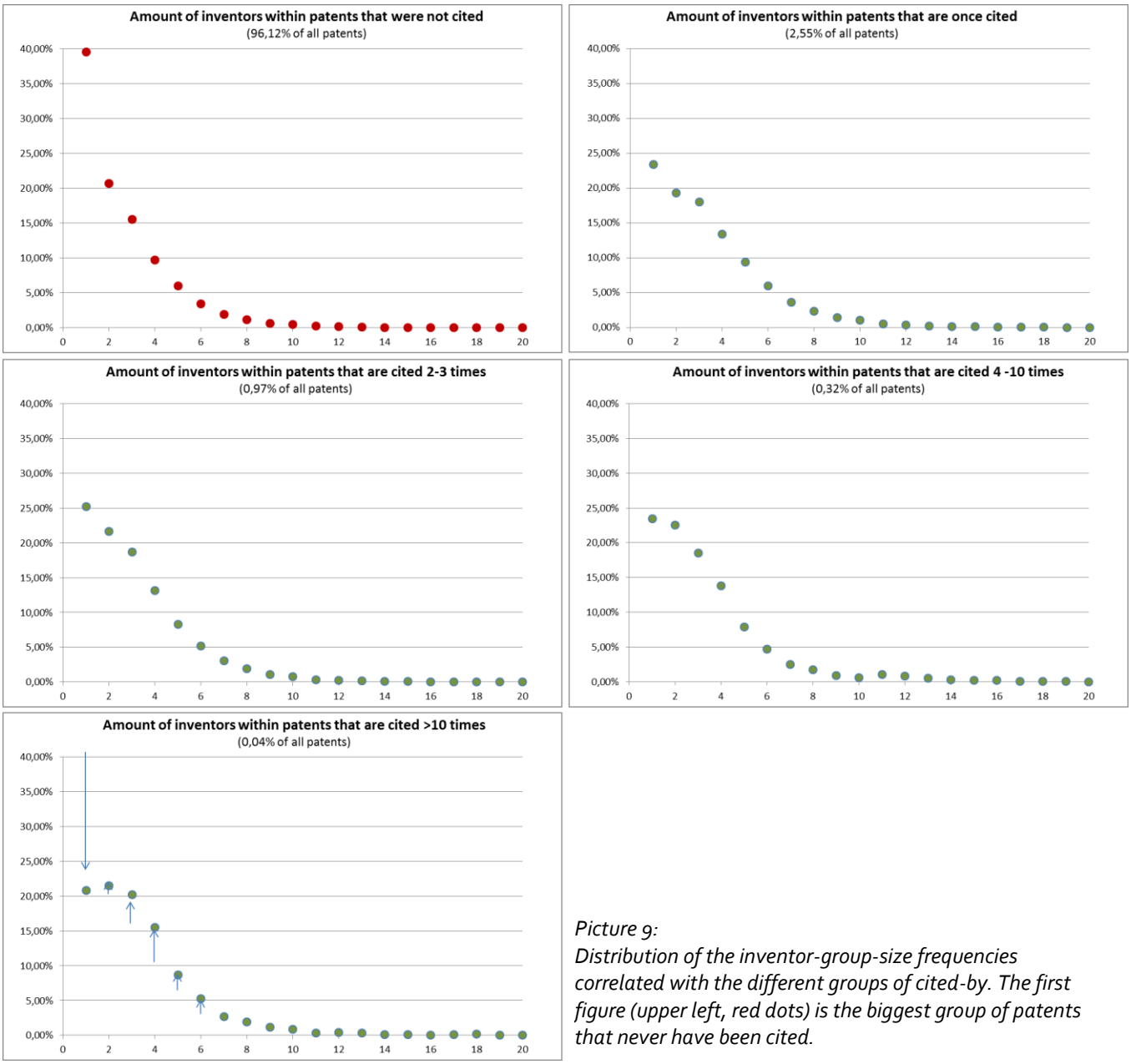
e) Inventors per forward citation

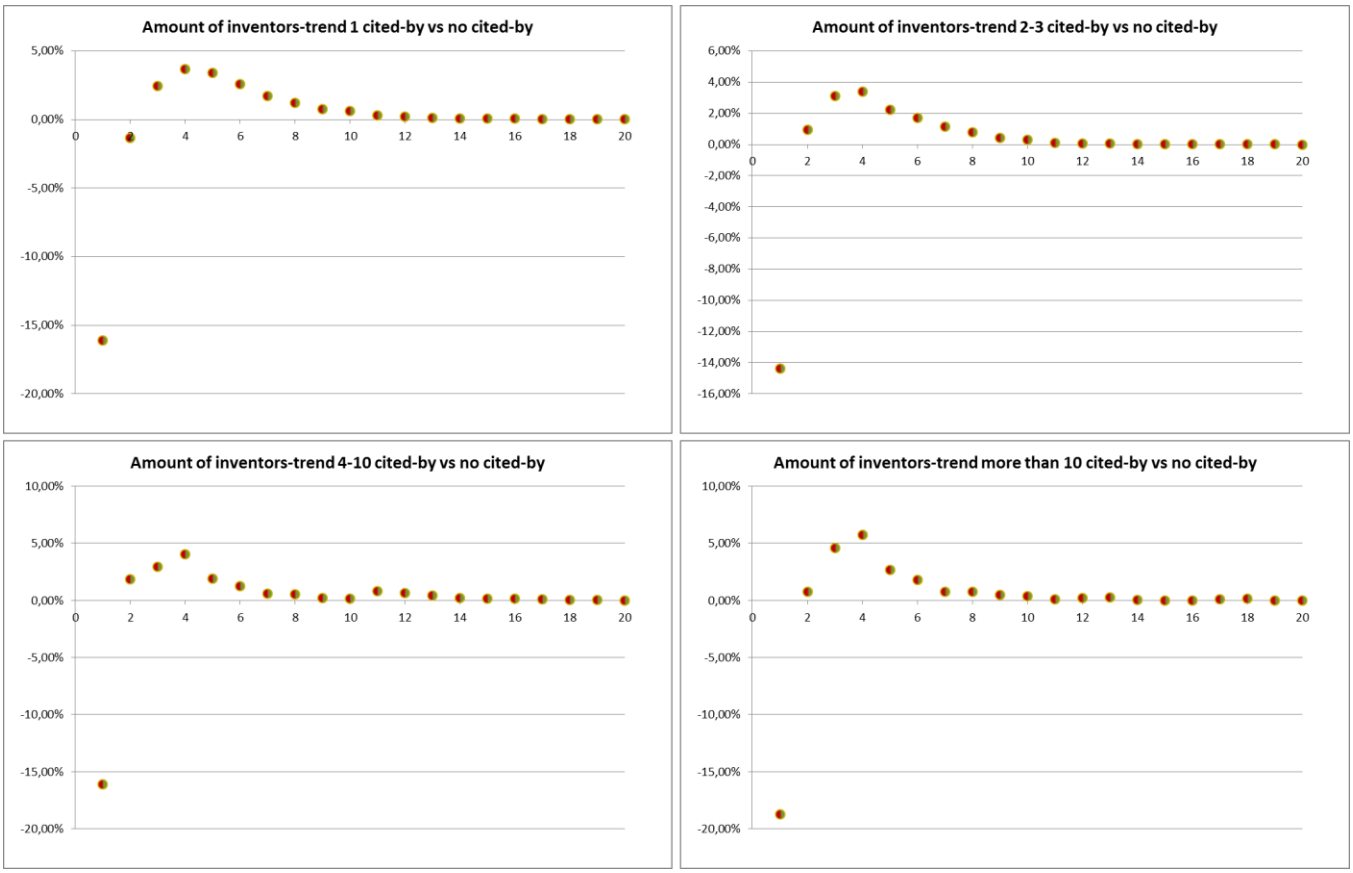
The cited-by is supposed to be a very strong indicator for high quality patents[10]: The more foreign cited-by a patent counts, the higher its value is supposed to be[11][12]. That is why exactly the same analysis was done here. Due to the fact that only very few patents are cited (3,88% of all patents were cited at least once, 96,12% were never cited) groupings were made in order to ensure that statistical relevance is given. Thus, according to the frequencies in forward citations (see picture 5) 5 different distributions have been made: the biggest group of no forward-citations, the group of one forward-citation, 2-3 citations, 4-10 citations and more of 10 citations.



Picture 9:
Distribution of the inventor-group-size frequencies correlated with the different groups of cited-by. The first figure (upper left, red dots) is the biggest group of patents that never have been cited.

[10] Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. The Rand journal of economics, 36(1), 16–38.
[11] Dahlin, K., & Behrens, D. (2005). When is an invention really radical?: Defining and measuring technological radicalness. Research Policy. (34), 717–737.
[12] Alcácer, J., & Gittelman, M. (2006). Patent citations as a measure of knowledge flows: The influence of examiner citations. The review of economics and statistics, 88(4), 774–779.

The trend seems to be quite similar to the analysis before, where the family sizes have been analysed (picture 7). The more often a patent gets cited, the relatively bigger the size of multiple inventors become. Very obvious to see is that the group of single-inventor patents are decreasing significantly the more often a patent gets cited – from a statistical point of view, of cause.
In order to make this even more visible, the trend was analysed by showing the changes of shares from one group of cited-by patents to the group of patents without cited-bys.



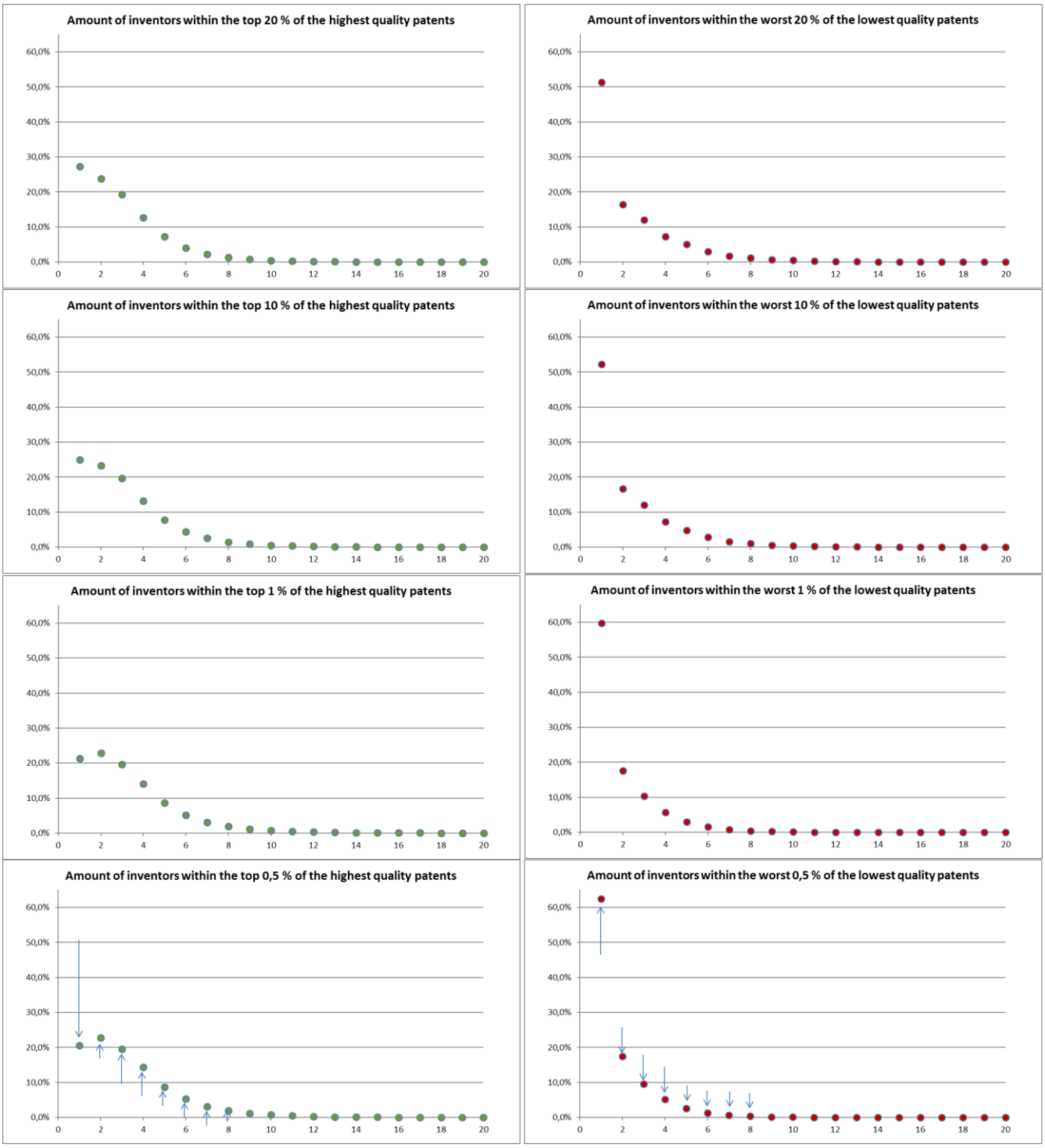
Picture 10:
Changes in frequencies of the different cited-by groups in comparison to not cited patents.

The trend of amount of inventors being involved in one invention is very obvious: The more often patents are cited, the more often 2 or more inventors are involved. The strongest increase of involved inventors for groups of cited patents is observable in the group of four inventors. The strongest decrease in size is again in the one-inventor patents group and reflects the picture of family-size frequencies.
Of cause this analysis does only take the changes in certain groups into account, not the total amount of patents that were filed: the total size of one-inventor patents is 4 times higher than the four-inventor patents group, the total sum of two-inventor patents is double in size compared to the four-inventor patents.

f) Inventors per patent quality

The problem of the above statistics is that there seem to be a strong correlation between inventor amount and family size as well as inventor amount and forward-citations, but the statistics does not show if the big sized patent portfolios are also those ones that are often cited. Hence in a final step multiple quality indicators were summarized and afterwards correlated with the inventor amounts. With this analysis a direct correlation between high qualitative patents and inventor amounts should be investigated. The

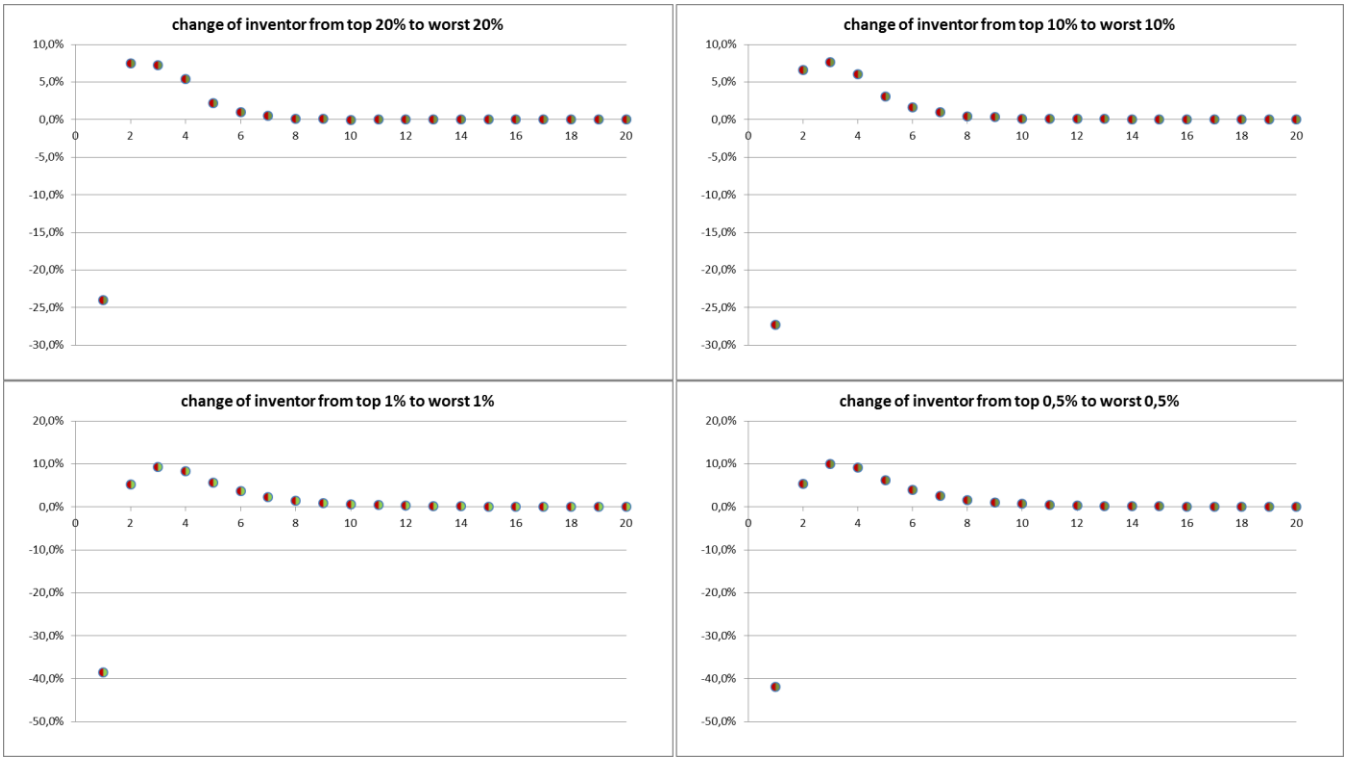
quality indicator here took the family size, the forward citations into account. The procedure is exactly the same like in the two analysis steps before. The analysis was made her for the top 20%, 10%, 1%, 0,5% and in direct comparison the worst 20%, 10%, 1%, 0,5%



Picture 11:
Changes in frequencies of inventor-group sizes in direct comparison: left (green symbols): best 20%, 10%, 1%, 0,5%, right (in red symbols) the worst 20%,10%, 1%, 0,5%.

One of the biggest surprises in the analysis showed in picture 11 is that the distributions among the worst group – the diagrams to the right hand – does not show significant changes in

contrast to the "tops" group to the left. Only the group of one-inventor patents becomes bigger the worse the group of inventions become. Here again the picture is similar to the comparisons that were done before within the single indicators. Here the distribution-picture is maybe even more significant than in the single distributions. The direct comparison of the tops (left diagrams) to the worst (right diagrams) shows the trend quite obviously: the more valuable the patents become, the more often multiple inventors are assigned. Very typical here is the picture of 2 inventors having most occurrences in total for the top 1% inventions. The group of one inventors has the strongest decrease and are the biggest group for the worst 1% inventions: the more valuable the patent-groups are, the stronger the decrease in the one-inventor group. In order to make the changes more obvious, the differences were taken from to top 20% to the worst 20%, top 10% to worst 10% etc.



Picture 12:
Difference of frequencies between the best and the worst groups: best/worst 20%, 10%, 1%, 0,5%, from upper left to lower right.

Analysing the changes from the group of worst valued patents to the best valued patents-groups the trend is again most obvious towards multiple inventor-groups: The more valuable the patents become, the higher the tendency of multiple inventors. Looking at the 0,5% and 1% best/worst comparison, then the biggest increase is observed in the group with 3 and 4 inventors. Generally, inventor-group-sizes of 2 to 6 inventors have increased in all groups, in the smallest groups (0,5%, 1%) even the inventor-groups up to 8 inventors per invention increased.

The analysis of differences does not take the total amount of invention into account, of cause.

Conclusion

The study has shown that there is a correlation between the amount of inventors per invention and the value, the invention can be assigned to. In the analysis has been shown that the frequency of multiple inventors is higher for valuable patents than for less valuable patents. Also the frequency for single-inventor patents is much smaller for the

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higher valued patents compared to less valuable ones. But the correlation seems not to be linear: the "ideal" inventor group sizes for the valuable patents seem to end at 8 inventors: here the significance compared to the lower valued patents ends. From a statistical point of view this means that the "ideal" inventor-group size ranges between 2 and 8 inventors, then the chance of having a higher valued patent is comparably higher. But the analysis must also take the distribution of total amount of invention into account. So the amount of 8 inventors per invention, for example, is only 1,17% of all inventions, compared to the single-inventor-inventions (38,97%) this is very small group. This means, that a potential indicator that takes the size of inventor groups into account, must also consider the distribution of frequencies. The analysis also shows that the inventor-indicator is just one additional indicator that links to a higher or lower quality respectively value of a patent family. This means when patent quality is measured, multiple indicators must be taken into account. The Inventor-group size is one of them.

Coming back to the initial theses in order to verify them:

1st single inventor-inventions are side inventions
According to the study, the single inventors have the highest frequency of all inventions, but the higher the patent value, the smaller the share of the single-inventor-inventions become. Statistically seen these have a lower value than multiple inventor-inventions.

2nd the more inventors are involved with an invention the higher the R&D Budget, the higher the quality.
This thesis can be stated statistically to a certain extent: the causality is not linear and not proportionately. Of cause the statistical analysis cannot make any statements regarding the R&D Budgets.

3rd the bigger the size of inventor team, the more inefficient the lower the patent quality
According to the statistically analysis, the high valued patents differentiate to the lower valued patents only in the group of 1-8 inventors per invention: A strong decrease in the one-inventor group, an increase in the group 2-8 inventors.

4th effective inventor-teams have a typical size.
The study has shown within a direct comparison of high value to low value patents, that there is a strong increase in inventor-team-sizes. The strongest team-size-increase was observed in the group of 2-6 inventors. The strongest decrease was observed in the single-inventor inventions.

The study was done for patent valuation based on indicators. So the result of this study will also improve the indicator-based qualitative patent valuation as well as the indicator based market analogy that will lead to a monetary value of a patent (family).

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