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Comparative analysis of patent-paper citations of five countries based on new indicators

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Background and objectives of the research

- Background
  - Demand for patent-paper citations as indicator of knowledge flows has been increasing (e.g. 5th Science and Technology Basic Plan in Japan). However, indicators to evaluate patent-paper citations from paper-side seemed still rare.
  - Recently, we proposed two indicators for assessment of knowledge flows at meso or macro level.
    - PPCI (Patent-Paper Citation Index)
      - Relative citedness of papers from patents
    - HFPPCI (High-Feature-Valued Patent Paper Citation Index)
      - Relative citedness of papers from patents of high-feature-values, which were more likely to contribute to innovation than ordinary patents
  - Evidence data on technological impacts at macro (country) level are essential for evaluation of basic research as well as future planning.
- Objectives
  - To analyze tendencies of technological impacts in macro (country) level, since such data were still scarce.
  - To grasp characteristics of the indicators for practical use and their improvement.

Data

Patent data

- PATSTAT 2016 Spring edition
- Counted by DOCDB family to avoid duplicate count of same invention
  - Restricted to patent families which contain published patent
- Earliest filing year of patent applications within a patent family was used as an filing year of the patent family, .
- Only IPR type "patents"(neither design patents nor utility models) was included to analysis.

Paper data

- Science Citation Index Expanded edition of the Web of Science (1981-2015)
- 22 categories of Essential Science Indicators (ESI) were attributed as disciplines
  - However, "Multidisciplinary" was excluded from the analysis, since most of papers classified in the discipline were re-classified into the rest of the disciplines.
- 5 disciplines of small number of papers cited in patents were omitted to present in figures, however, they were included to calculation of indicator values of country total.

All NPLs appeared in the patent data were matched to each record in the WoS.

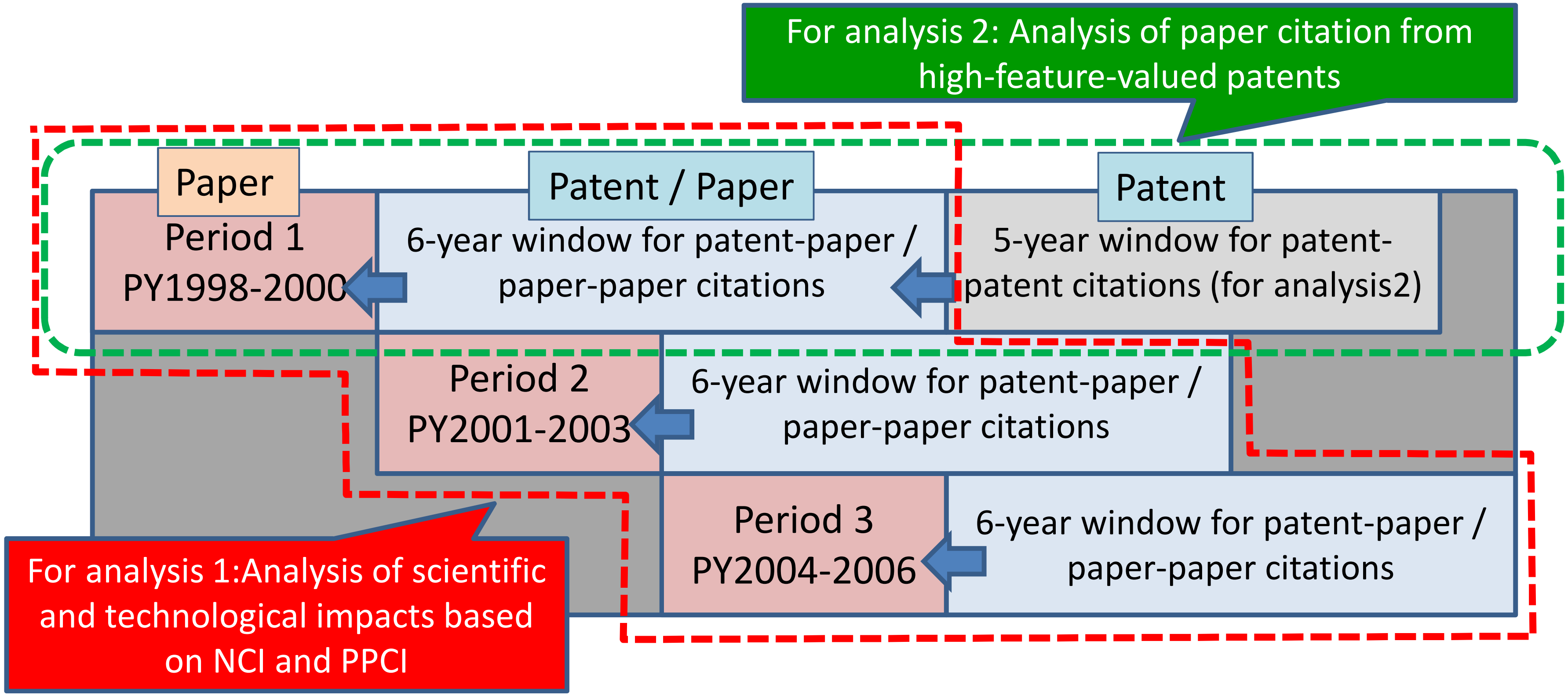
Disciplines

CODE	Discipline	CODE	Discipline
AGS	Agricultural Sciences	MOL	Molecular Biology & Genetics
BBI	Biology & Biochemistry	NEB	Neuroscience & Behavior
CHE	Chemistry	PHT	Pharmacology & Toxicology
CLM	Clinical Medicine	PHY	Physics
CPS	Computer Science	PLA	Plant & Animal Science
ENE	Environment/Ecology	ECB	Economics & Business
ENG	Engineering	MAT	Mathematics
GSC	Geosciences	PSS	*Psychiatry/Psychology*
IMU	Immunology	SPA	*Space Science*
MTS	Materials Science	SSS	*Social Sciences, general*
MIC	Microbiology		

Included in calculation but not presented by discipline

Times scheme

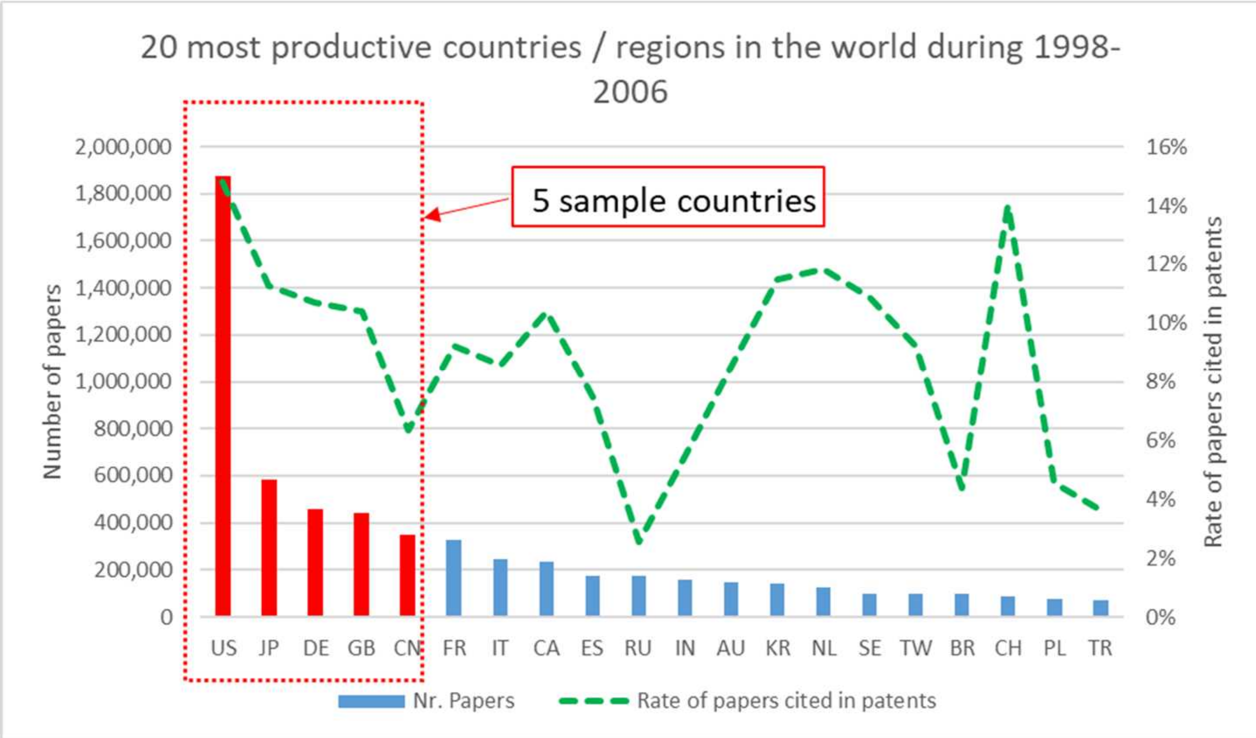
- Papers were classified into three periods analyze chronological changes of the indicator value (analysis 1)
- Patent–paper citations were counted for 6 year after their publication of the paper.
- Citations of "patents which cited papers" from patents were counted for 5 years after publication of the "patent which cited papers" (following Squicciarini, Dernis & Criscuolo 2013).



Squicciarini M., Dernis H. & Criscuolo C.(2013), "Measuring Patent Quality: Indicators of Technological and Economic Value", OECD Science, Technology and Industry Working Paper 2013/03, OECD Publishing, Paris, https://doi.org/10.1787/5k4522wkw1r8-en.

Selection of sample countries

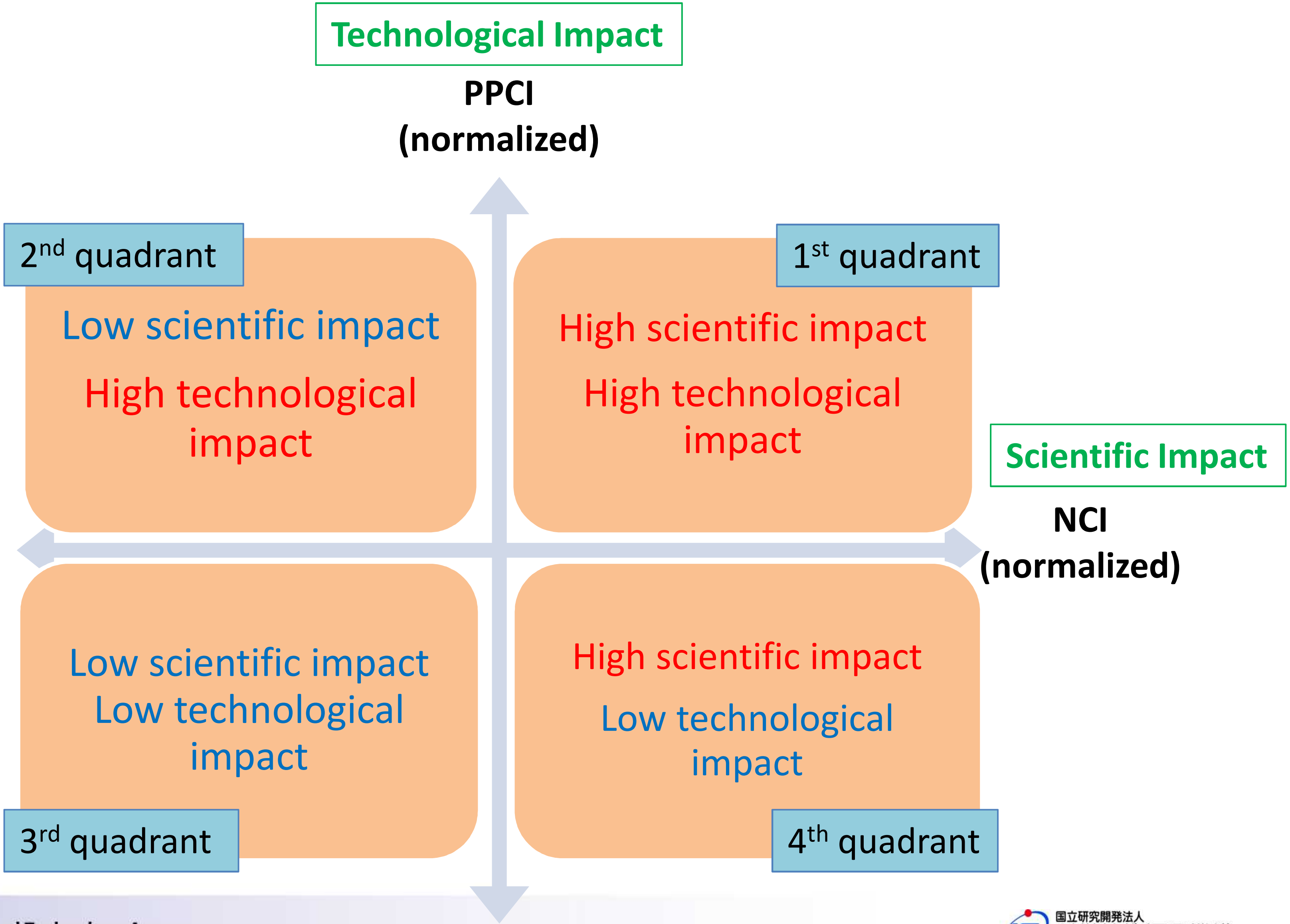
- Top 5 produces of scientific papers in the world during 1998–2006 were selected as samples.



Analysis 1:

Analysis of scientific and technological impacts based on NCI and PPCI

X-Y plotting of scientific and technological impacts



PPCI: indicator to overview relative technological impacts

Definition of PPCI

- Rate of papers cited in patents in the target's papers divided by rate of papers cited in patents in all papers in the world.
- Distribution of patent-paper citations was very skewed, and only limited papers were cited in patents, therefore, we focused on rate of cited papers rather than number of citations.

Definition of NCI (Normalized Citation Impact)

- Ratio of number of paper-paper citations per paper of a target and those of the world.
- Defined in "InCites indicators handbook" provided by Clarivate Analytics.

Both PPCI and NCI are calculated by discipline and document type.

Mathmatical expression of PPCI

PPCI of each discipline and document type

$$p_{ijd} = \frac{(n'_{ijd}/n_{ijd})}{(N'_{id}/N_{id})}$$

where,

n_{ijd}: Number of target *j*'s papers with document type *d* published in discipline *i*.

n'_{ijd}: Number of target *j*'s papers cited in patents with document type *d* published in discipline *i*.

N_{id}: Number of total papers with document type *d* published in discipline *i*

N'_{id}: Number of total papers cited in patents with document type *d* published in discipline *i*

Definition of PPCI

PPCI of whole target (country)

$$P_j = \frac{\sum_i \sum_d p_{ijd} \times n_{ijd}}{\sum_i \sum_d n_{ijd}} = \frac{\sum_i \sum_d \left(N_{ijd} \times n'_{ijd} / n_{ijd}\right)}{\sum_i \sum_d n_{id}}$$

Normalization for plotting X-Y planes

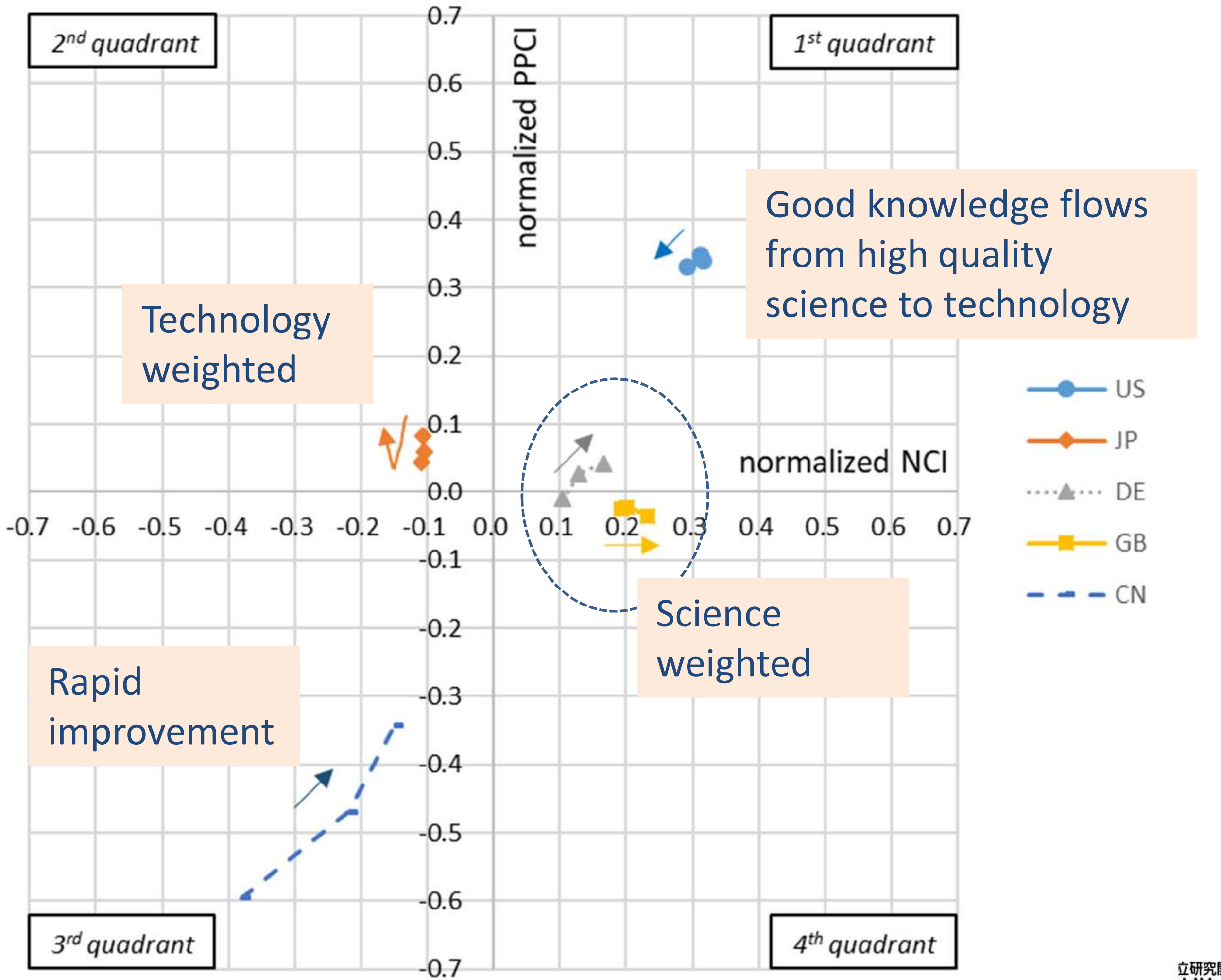
$$\text{Normalized } P_j = \frac{(P_j^2 - 1)}{(P_j^2 + 1)}$$

This normalization was also applied to NCI

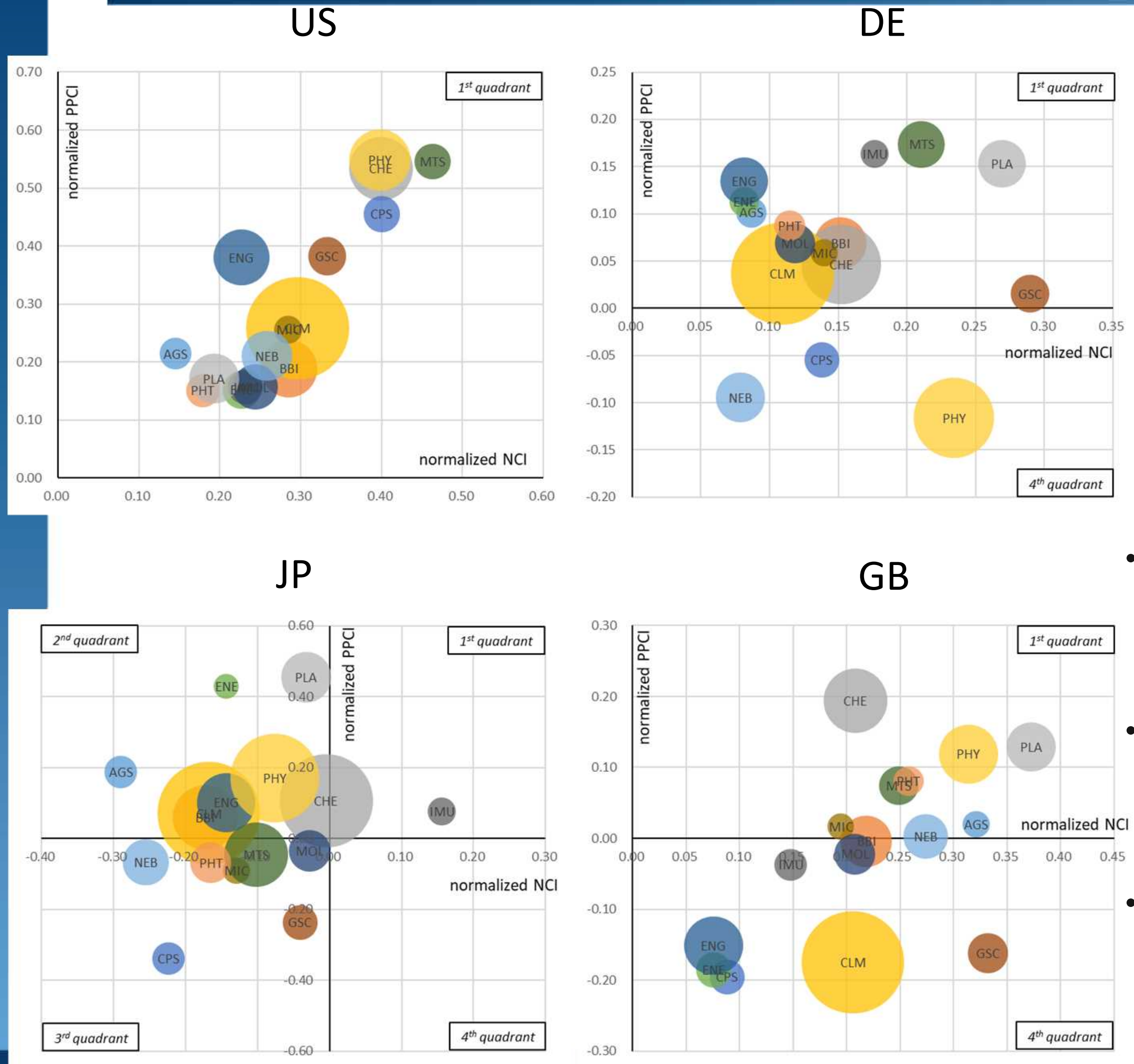
Result

NCI and PPCI of five countries（period 1-3）

- Locations of the countries were relatively stable except for China.
- 5 countries were categorized in four types according to locations and their changes in time.



NCI and PPCI of the five countries (period 3: 2004-2006))



- US: All disciplines were located on 1st quadrant. Scientific and technological impacts were correlated each other.
- DE, GB: All disciplines were located on 1st or 4th quadrant. Two large disciplines (CLM, PHY) showed opposite tendencies for PPCI.
- JP, CN: Most of disciplines were located on 2nd or 3rd quadrant.

Analysis 2:

Analysis of paper citations from high-feature-valued patents

Definition of High-Feature-Valued Patent Paper Citation Index (HFPPCI)

- Rate of papers cited in high-feature-valued patents in targets' papers divided by those in the world's papers.
- Differences of document types and disciplines are ignored because of small sample size (although the index was weighted by discipline in Yamashita 2018).
- Mathematical expression is as follows;

$$p_j^h = \frac{(m'_j/n_j)}{(M'/N)}$$

where,

n_j: Number of target j's papers.

m'_j: Number of target j's papers cited in high feature valued patents published.

N: Number of total papers published

M': Number of total papers cited in high feature valued patents published

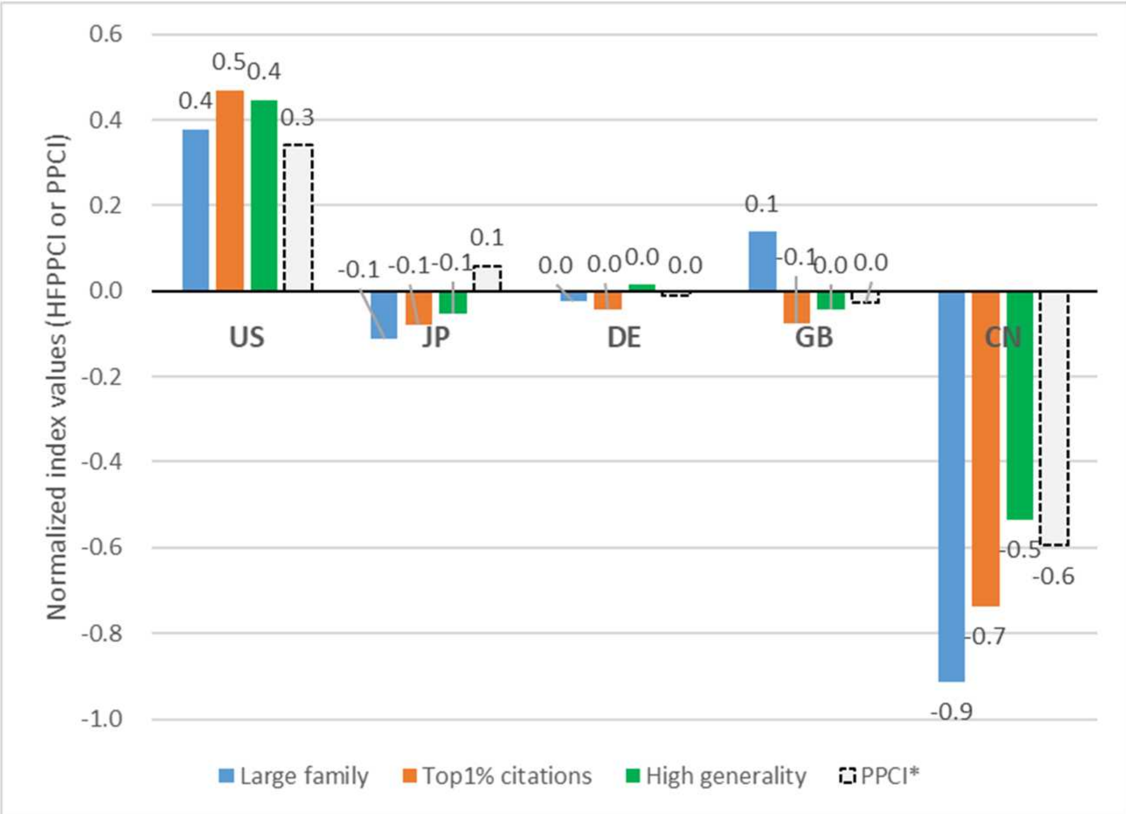
Selection of patent feature values and their thresholds

- Three patent feature values, which were components of “composite index 4” defined in Squicciarini, Dernis & Criscuolo (2013), and available in Patstat, were selected.
  - Patent family size (equal or more than 15)
  - (Patent-patent) forward citations (top 1%)
  - Patent generality index (equal or more than 0.85)

Squicciarini M., Dernis H. & Criscuolo C.(2013), “Measuring Patent Quality: Indicators of Technological and Economic Value”, OECD Science, Technology and Industry Working Paper 2013/03, OECD Publishing, Paris, https://doi.org/10.1787/5k4522wkw1r8-en.

Result

HFPPCIs of the five countries（period 1）



* PPCI was weighted by discipline and document type

- Countries of high/low PPCI tended to show high/low HFPPCI values, respectively.
  - Deviation from PPCI values should be focused as well as HFPPCI values themselves.
  - Japan showed low HFPPCIs, although its PPCI showed opposite tendency.

Conclusion and Discussion (1)

- Tendencies of 5 countries were illustrated by PPCI and HFPPCIs.
  - US
    - It showed good structure of knowledge flows.
      - It showed relatively high impact for both scientific and technological aspects, both for all and high-feature-valued patents.
      - It showed clear correlations between scientific and technological impacts. It might suggest existence of linkages between high quality science and technology.
  - Japan
    - It showed relatively high knowledge flows however, impact to "high impact" technologies were limited. Improving scientific impacts of researches might be essential for improvement of its impact to development of "high impact" technologies.
  - Germany and UK
    - They weighted relatively to science rather than relationships to technology, however, Germany improved its technological impact period by period.
  - China
    - It showed remarkable improvement both in scientific and technological impacts period by period, so its trend should be traced continuously.

Discussion and Conclusion（2）

- PPCI is useful to overview both scientific and technological impact of targets, in combination with use of indicators of scientific impacts, as NCI.
- HFPPCIs likely correlate to PPCI. Therefore, their deviations from PPCI provide valuable insights of structures of national innovation systems.
- Continuous researches concerning citations from high-feature-valued patents should be indispensable, because, following issues are important.
  - Exploration of other patent feature values, including meanings of their paper citations.
  - Review of threshold values.
  - Shortening observation periods for practical use of the indicators.

Thank you for your attention

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