The user is asking me to translate a Chinese academic title to English. They' ve provided some context about previous translation attempts and detected Chinese characters, but they haven't actually given me the Chinese title text to translate. Let me re-read their message carefully: "TEXT TO RETRA···

Authors: The user has provided a single Chinese character "杨珪"which appears to be a name. This is not a scientific paper or academic text. The instructions are very specific about translating academic papers with LaTeX commands, tags, etc., but this input doesn' t contain any of those elements.

Let me analyze the input: - "杨珪" - This is a Chinese name. "杨" is a common surname (Yang) and "珪"is a given name (Gui). - There are no LaTeX commands - There are no tags - There are no citations - This is not an academic paper

The user is asking me to translate this name. According to the instructions, I should: 1. Preserve ALL LaTeX commands and placeholders - not applicable here 2. Preserve ALL citation commands - not applicable here 3. **PRESERVE ALL ···paragraph wrapper tags EXACTLY** - not applicable here 4. Maintain academic tone and formal scientific writing style - not really applicable for a name 5. Use precise technical terminology - not applicable 6. Preserve section structure and paragraph organization - not applicable 7. Translate all content completely - this is just a name

Since there are no tags or other structural elements, and the input is just a name, I should simply provide the English translation of the name. The standard way to translate Chinese names is to use Pinyin with the surname first, or sometimes given name first in Western contexts.

"杨珪" would be "Yang Gui" in Pinyin.

However, the instructions say "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)." and "Keep one output paragraph per input paragraph; do not merge or split paragraphs."

Since the input is just a name without any tags, I should just output the translated name. But the instructions emphasize preserving tags. Since there are none, I don' t need to add any. The input is not in the format expected, so I should just provide the direct translation.

Let me reconsider: The user might be testing the system, or this might be a fragment of a larger text. But based on what I' m given, I should just translate the name.

The most appropriate translation is "Yang Gui". In academic contexts, Chinese names are typically rendered in Pinyin„ The user has provided a single name "罗雯琪" which appears to be a Chinese name. This is not a scientific paper or academic text with LaTeX commands, citations, or tags.

The task is to translate from Simplified Chinese to English with the highest accuracy and academic tone, following specific rules for preserving LaTeX, citations, and tags. However, the input is just a name.

For Chinese names, the standard academic translation convention is: - Keep the original Chinese characters if the name is already established in literature - Or provide the pinyin transliteration with family name first, or given name first depending on context

Since this is just a name without any context, and the user is asking for translation following academic paper conventions, I should: 1. Recognize this as a personal name (罗 = Luo, 雯琪 = Wenqi) 2. In academic contexts, Chinese names are often presented as "Luo Wenqi" (family name first, then given name) 3. Or sometimes "Wenqi Luo" if Western name order is preferred

Given the academic context and that this appears to be a Chinese name, the most appropriate translation would be the pinyin transliteration. In Chinese academic papers, names are typically written with the surname first, so "Luo Wenqi" would be the standard format.

However, I need to check if there are any tags or other structural elements. The input is just "罗雯琪" with no tags, no LaTeX, no citations.

Since the user wants me to follow the CRITICAL REQUIREMENTS and OUTPUT RULES, but the input doesn' t contain any of the structural elements mentioned, I should just provide the translation of the name itself.

The most appropriate academic translation would be: Luo Wenqi

But wait, I should consider if this might be part of a larger text that was supposed to be included. The user just provided "罗雯琪". Let me re-read the instructions.

The instructions say "Translate from Simplified Chinese to English with the highest accuracy and academic tone." and specify rules about preserving LaTeX, citations, and tags. Since none of these are present, I just need to translate the name.

In academic contexts, Chinese names are typically: 1. Written in pinyin 2. With surname first (Luo Wenqi) 3. Or sometimes given name first if the author prefers Western order (Wenqi, The user has provided a very short input: "戴睿". This appears to be a Chinese name. The task is to translate it from Simplified Chinese to English with the highest accuracy and academic tone, following the critical requirements and output rules provided.

Let me analyze the requirements: 1. Preserve ALL LaTeX commands and placeholders - not applicable here as there are none 2. Preserve ALL citation commands - not applicable here 3. **PRESERVE ALL ⋯paragraph wrapper tags EXACTLY** - not present in the input 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - obey the glossary strictly 6. Preserve section structure and paragraph organization 7. Translate all content completely - do not omit any information

Output rules: - Return ONLY the translated text (no explanations, no quotes, no headings) - Keep one output paragraph per input paragraph - **Maintain exact count and IDs of ⋯tags** - not applicable - Do NOT add Markdown formatting unless present in source - Preserve original line breaks

The glossary provided is: - 机器学习 => machine learning - 深度学习 => deep learning

The input is "戴睿". This is a Chinese name. In academic contexts, Chinese names are typically transliterated following specific conventions: - The surname comes first: 戴 (Dài) - The given name comes second: 睿 (Ruì) - In English academic papers, Chinese names are often written as: DAI Rui (all caps for surname) or Dai Rui (with surname first) or Rui Dai (Western order)

The most common and formal academic convention for Chinese names in English publications is to either: 1. Keep the original order: Dai Rui 2. Use all caps for surname: DAI Rui 3. Sometimes with hyphen: Dai-Rui (less common for this name)

Given the academic context and the need for highest accuracy, I should use the standard pinyin transliteration. The name "戴睿" would be: - Surname: 戴 (Dài) -> Dai - Given name: 睿 (Ruì) -> Rui

In formal academic writing, Chinese names are typically rendered in one of these formats: - Dai Rui (most common in text) - DAI, Rui (in reference lists) - DAI Rui (in, The user has provided a very short input: "许智淑". This appears to be a Chinese name. The task is to translate it from Simplified Chinese to English with the highest accuracy and academic tone, following the critical requirements provided.

Let me analyze the requirements: 1. Preserve ALL LaTeX commands and placeholders - not applicable here as there are none 2. Preserve ALL citation commands - not applicable here 3. **PRESERVE ALL ⋯paragraph wrapper tags EXACTLY** - not present in input 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - obey the glossary strictly 6. Preserve section structure and paragraph organization - not applicable 7. Translate all content completely - do not omit any information

The glossary provided is: - 机器学习 => machine learning - 深度学习 => deep learning

But “许智淑” is a name, not a technical term from the glossary.

For Chinese names in academic contexts, the standard practice is: - Use the pinyin transliteration - Follow the English convention of given name first, family name last - Capitalize appropriately

“许智淑” is: - 许 (Xǔ) - family name (surname) - 智淑 (Zhìshū) - given name

In academic English, this would typically be written as “Zhishu Xu” (given name + family name).

However, I need to consider if there are any tags. The input is just “许智淑” without any tags. The instructions say “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).” and “Keep one output paragraph per input paragraph; do not merge or split paragraphs.”

Since there’ s no tag in the input, I should not add one. The input is just a name, which is not a paragraph. I should just provide the translation.

But wait, let me re-read the instructions carefully. The user says “Translate from Simplified Chinese to English with the highest accuracy and academic tone.” The input is “许智淑”. This is a name.

The critical requirement #3 says: “PRESERVE ALL …paragraph wrapper tags EXACTLY - these are structural markers that identify paragraphs and MUST remain untouched with their IDs”. Since there are no such tags in the input, The user has provided a very short input: “黄晴明”. This appears to be a Chinese name. Let me analyze what needs to be done:

1. The input is just “黄晴明” - no LaTeX, no citations, no tags
2. This is likely a name that needs to be translated or transliterated
3. The instructions say to translate from Simplified Chinese to English with academic tone
4. The critical requirements mention preserving LaTeX, citations, and tags, but none are present
5. The glossary provided only covers “机器学习 => machine learning” and “深度学习 => deep learning”, which are not relevant here

For Chinese names, the standard academic practice is: - Use Pinyin transliteration - Family name first, then given name (often with a space) - “黄晴明” would be “Huang Qingming”

However, I need to consider if this is part of a larger context. The user might be testing the system or providing a fragment. Since there are no tags or other structural elements, I should just provide the transliteration of the name.

But wait - the instructions are very specific about preserving tags. If the input doesn' t have them, should I add them? Let me re-read:

"CRITICAL REQUIREMENTS: 3. **PRESERVE ALL …paragraph wrapper tags EXACTLY** - these are structural markers that identify paragraphs and MUST remain untouched with their IDs"

"OUTPUT RULES: - **Maintain exact count and IDs of …tags** - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs"

The input has ZERO tags. So the output should also have ZERO tags. I should not add them.

The input is just "黄晴明". This is a name. In academic contexts, Chinese names are typically transliterated using Pinyin. "黄" is the surname (Huang), and "晴明" is the given name (Qingming).

So the translation/transliteration should be: "Huang Qingming"

I should not add any extra formatting, explanations, or tags. Just the transliterated name.

Let me double-check the instructions: - "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)." - ", The user has provided a very short input:" 齐佰超". This appears to be a Chinese name. Let me analyze the requirements:

1. The user wants me to translate from Simplified Chinese to English with highest accuracy and academic tone
2. I must preserve ALL LaTeX commands and placeholders exactly
3. I must preserve ALL citation commands ([?], ??, (??), etc.) exactly
4. **PRESERVE ALL …paragraph wrapper tags EXACTLY**
5. Maintain academic tone and formal scientific writing style
6. Use precise technical terminology - obey the glossary strictly
7. Preserve section structure and paragraph organization
8. Translate all content completely - do not omit any information

However, the input "齐佰超" is just a name. It doesn' t contain: - Any tags - Any LaTeX commands - Any mathematical formulas - Any citations - Any technical content

This is simply a Chinese name that needs to be transliterated into English. The standard academic practice for Chinese names is to use Pinyin. "齐佰超" would be "Qi Baichao".

But wait, let me double-check the requirements. The user says "Translate from Simplified Chinese to English". A name is not really "translated" but rather "transliterated". In academic contexts, Chinese names are typically rendered in Pinyin.

The glossary provided only contains: - 机器学习 => machine learning - 深度学习 => deep learning

These don' t apply to this input.

Since there are no tags in the input, I should not add any. The output should be just the transliterated name. However, the instructions say "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)."

So the simplest and most correct output would be: Qi Baichao

But let me consider if there' s any ambiguity. Could "齐佰超" be something else? - 齐 (Qi) - a common Chinese surname - 佰 (Bai) - means "hundred" but is used in names - 超 (Chao) - means "super" or "surpass" but is used in names

This is clearly a personal name. In academic contexts, the standard is to use Pinyin with surname first, capitalized: Qi Baichao.

The instructions are very specific about preserving, The user has provided "杨玥" which appears to be a name. This is likely the author name from a paper. I need to translate this from Chinese to English.

"杨" is the surname "Yang" "玥" is the given name "Yue"

In academic papers, Chinese names are typically transliterated using Pinyin. The standard format is either: - Yang Yue (given name first, surname last - Western order) - Yue Yang (surname first, given name last - Eastern order, but often used in Chinese academic contexts)

However, looking at the context of the task, this seems to be part of a scientific paper translation. In most international academic publications, Chinese names are written in Western order: Given name + Surname.

So "杨玥" should be translated as "Yang Yue" .

But wait, I need to check the instructions again. The user said "Translate from Simplified Chinese to English with the highest accuracy and academic tone." and "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)."

The input is just "杨玥" . This is a name. In academic contexts, Chinese names are typically: 1. Kept in Pinyin: Yang Yue 2. Sometimes with surname first: Yue Yang (less common in Western publications) 3. Sometimes with a hyphen: Yang Yue

The most standard academic practice for Chinese names in international publications is to use the Western order: Given name + Surname, so "Yue Yang" . However, many Chinese authors prefer to keep their surname first even in English publications, writing "Yang Yue" .

Let me think about the most common practice in academic papers. In many Chinese academic papers translated to English, authors often keep the Chinese order (surname first) but capitalize the surname: YANG Yue, or write it as Yang Yue. The given name "玥" is transliterated as "Yue".

Given that this is a single name without context, I should provide the most standard academic transliteration. The most common format in international journals is: - Surname first, given name second, with surname sometimes in all caps: YANG Yue - Or simply: Yang Yue

Since the user wants "highest accuracy and academic tone", I should use the format that is most common in academic publications. The format "Yang Yue" (with surname first) is widely accepted and understood in academic contexts, The user has provided a very short input: "曹丽". This appears to be a Chinese name. The task is to translate from Simplified Chinese to English with the highest accuracy and academic tone, following the critical requirements and output rules provided.

Let me analyze the input: - It's just two characters: "曹丽" - This is clearly a person's name - In Chinese names, the family name comes first, followed by the given name - "曹" (Cáo) is a common Chinese surname - "丽" (Lì) is a common given name meaning "beautiful" or "pretty"

According to the instructions: 1. I need to preserve ALL LaTeX commands and placeholders - but there are none here 2. Preserve ALL citation commands - but there are none here 3. **PRESERVE ALL …paragraph wrapper tags EXACTLY** - but there are none here 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - but this is just a name 6. Preserve section structure and paragraph organization - there's no structure 7. Translate all content completely - do not omit any information

The output rules state: - Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent) - Keep one output paragraph per input paragraph; do not merge or split paragraphs - **Maintain exact count and IDs of …tags** - but there are none

Since there are no tags in the input, I should not add any. The input is just a name, which should be translated following standard academic conventions for Chinese names.

In academic contexts, Chinese names are typically romanized using Pinyin. The standard format is: - Either: Family name first (Cao Li) - common in Chinese academic publications - Or: Given name first (Li Cao) - common in Western publications

However, the most common and respectful approach in academic translation is to keep the original Pinyin with the family name first, unless there's a specific known preference of the individual. "Cao Li" would be the standard Pinyin representation.

Since there are no paragraph tags, I should just provide the translated name directly. The instructions say "Return ONLY the translated text for the given input” and “Keep one output paragraph per input paragraph” . Since there’ s no paragraph structure„ Yang Gui

Date: 2024-09-11T00:00:00+00:00

Abstract

[Purpose/Significance] Against the backdrop of new quality productive forces construction, participation in scientific and technological frontiers and hotspot research reflects important aspects of innovation and leadership. [Method/Process] This study utilizes the series of research frontier reports from the Chinese Academy of Sciences and Chinese Academy of Engineering, along with Elsevier’ s topic prominence indicators, to analyze China’ s and (new) first-tier cities’ participation in scientific research frontiers and hotspots. [Results/Conclusion] The study finds that China’ s participation in global scientific research frontiers has made tremendous progress, but the research quality still requires substantial improvement. Overall, both China as a whole and its (new) first-tier cities tend to follow more than they lead. From a disciplinary field perspective, mathematics/computer science and engineering, chemistry/chemical engineering and materials science, physics, earth sciences, ecology/environmental science and engineering, biology/agricultural science and engineering, and energy and mining engineering demonstrate strong performance in both leading and following frontiers; overall, frontier research in engineering and technology fields outperforms that in natural sciences. From a subject perspective, frontier topics in (new) first-tier cities are distributed across relatively traditional disciplines with limited influence, and there remains a gap in performance in cutting-edge disciplines with substantial frontier distribution such as engineering, biochemistry/genetics and molecular biology, and medicine. Geographically, Chinese institutions participating in global scientific research frontiers are primarily located in coastal cities. In terms of city performance, Beijing stands out prominently in research frontiers, followed by Shanghai, Guangzhou, Wuhan, Nanjing, Hangzhou, Xi’ an, Changsha, Chengdu, and Shenzhen with commendable performance. Regarding topic frontiers, Beijing demonstrates outstanding performance across three dimensions: contribution, frontiers, and influence, with Guangzhou, Shanghai, Nanjing, Wuhan, and other cities following closely behind. Dongguan, Suzhou, Zhengzhou, Shenzhen, and Shenyang exhibit particularly strong performance in the frontiers of academic research, while other cities show average performance across all indicators.

Full Text

Frontiers and Hotspots Participation of Scientific and Technological Research in China and (New) First-Tier Cities Under the Background of New Quality Productive Forces Construction

Yang Gui[1]*, Luo Wenqi[1], Dai Rui[1], Xu Zhishu[2], Huang Qingming[3], Qi Baichao[4], Yang Yue[5], Cao Li[6]

[1] Development and Planning Division, Sichuan University, Chengdu 610065, China
[2] Business School, Sichuan University, Chengdu 610065, China
[3] School of Mechanical Engineering, Sichuan University, Chengdu 610065, China
[4] School of Economics, Sichuan University, Chengdu 610065, China
[5] West China School/Hospital of Stomatology, Sichuan University, Chengdu 610065, China
[6] Sichuan University-The Hong Kong Polytechnic University Institute for Disaster Management and Reconstruction, Chengdu 610207, China

Abstract

[**Purpose/Significance**] Under the background of new quality productive forces construction, participation in frontier and hotspot research in science and technology reflects important aspects of innovation and leadership. [**Method/Process**] This paper analyzes the participation of China and its (new) first-tier cities in scientific and technological research frontiers and hotspots by utilizing the series of Research Fronts reports from the Chinese Academy of Sciences and Chinese Academy of Engineering, along with Elsevier' s topic prominence indicators. [**Result/Conclusion**] The study finds that China' s participation in global scientific and technological research frontiers has improved tremendously, though the level of research still requires significant enhancement. Both the nation as a whole and (new) first-tier cities generally follow more than they lead. In terms of fields, mathematics/computer science and engineering, chemistry/chemical engineering and materials science, physics, earth sciences, ecology/environmental science and engineering, biological/agricultural science and engineering, and energy and mining engineering demonstrate both strong leadership and followership. Overall, frontier research in engineering and technology fields outperforms that in natural sciences. Regarding disciplines, frontier topics in (new) first-tier cities are distributed in relatively traditional disciplines with limited influence, showing gaps in frontier disciplines with large distributions such as engineering, biochemistry/genetics and molecular biology, and medicine. Geographically, Chinese institutions participating in global scientific and technological research frontiers are mainly located in coastal cities. In terms of city performance, Beijing stands out remarkably in research frontiers, followed by Shanghai,

Guangzhou, Wuhan, Nanjing, Hangzhou, Xi' an, Changsha, Chengdu, and Shenzhen with commendable performance. Regarding topic frontiers, Beijing demonstrates outstanding performance in contribution, prominence, and influence, followed by Guangzhou, Shanghai, Nanjing, and Wuhan. Dongguan, Suzhou, Zhengzhou, Shenzhen, and Shenyang show particularly strong performance in academic research prominence, while other cities perform averagely across all dimensions.

Keywords: Research Frontier; China; (New) First-Tier City; Publication Share; Prominence Percentile; FWCI

The user wants me to translate the "## 1 Introduction" section from Chinese to English. Let me analyze the text carefully.

Key requirements: 1. Preserve all math (none in this section) 2. Preserve all citations ([?], ??, (??)) - there are several [1-22], [23], [24], [25], [29], [30-42], [43], [44-49], [50-56] 3. Preserve figure/table markers (none in this section) 4. Maintain academic tone 5. Produce flowing, readable prose 6. Merge fragmented text into complete sentences 7. Skip garbage text (none here) 8. Use proper LaTeX formatting for any math (none here) 9. Romanize author names (none here) 10. Translate journal names (there' s "Science and Technology Daily" which should be italicized as a publication) 11. Use official English names for institutions (Chinese Academy of Sciences, Chinese Academy of Engineering, Elsevier) 12. No Chinese characters left

Let me break down the Chinese text:

"Science and technology constitute the core of modern national competition and development, having become a country' s key competitive advantage, while urban development has always been closely linked to scientific and technological progress."

This is a good opening sentence. I need to make it flow well in English.

"Current research on academic frontiers, apart from total literature in relevant fields, mostly focuses on discipline-specific studies [1-22], emphasizing theoretical 梳理."

"梳理" here means "sorting out" , "organizing" , "systematizing" . In academic context, it could be "theoretical systematization" or "theoretical organization" . Let me think about the best translation. "Theoretical 梳理" - this is about organizing or sorting out theories. "Theoretical synthesis" might be too strong. "Theoretical organization" or "theoretical systematization" works. I' ll go with "theoretical systematization" as it' s more academic.

"The" Urgently Needed Core Technologies" column in *Science and Technology Daily*' s 梳理 of 35 Chinese "chokepoint" core technologies [23] proposes directions for scientific research from national social needs."

Here "梳理" is used again. In this context, it' s about a report or analysis that sorted out/identified these technologies. "梳理" could be "analysis" , "survey"

, "review" . Given it' s a newspaper column doing this work, "analysis" or "survey" would fit. I' ll use "analysis" for this instance.

"Globally, numerous reports on research frontiers and development trends exist, such as the U.S. report on emerging science and technology trends [24], UNDP' s Development 4.0 [25], and relevant international conferences [29]."

This is straightforward. UNDP is United Nations Development Programme. "Development 4.0" should be kept as is.

"However, research on participation in research frontiers has been scarce due to difficulties in academically defining research frontiers and lacking a research foundation."

Good sentence, just needs polishing.

"With the aid of bibliometric data, academia has made progress in large-scale research across all disciplines globally."

Clear.

"Current research on research frontiers includes the series of Research Fronts reports from the Chinese Academy of Sciences and Chinese Academy of Engineering [30-42] and Elsevier' s topic prominence indicators, which together provide a relatively solid foundation and basic data for academic frontier research."

I need to check the official names. "Chinese Academy of Sciences" is correct. "Chinese Academy of Engineering" is correct. "Elsevier' s topic prominence indicators" - this seems to be a specific product, I should keep it as is or find the official name. The text says "Elsevier' s topic prominence indicators" so I' ll translate it directly.

"Based on this foundation, there have been related interpretations [43] and limited analyses [44-49]."

Good.

"This paper utilizes their data[2] to study the participation of China and first-tier cities, selecting four first-tier cities (Beijing, Shanghai, Guangzhou, and Shenzhen) and the top 13 cities by cumulative selection frequency among new first-tier cities in the past five years[3] (hereinafter referred to as (new) first-tier cities) as analytical subjects."

There are footnote markers [2] and [3]. I should preserve them. The term "新一线城市" is translated as "new first-tier cities" . The phrase "hereinafter referred to as (new) first-tier cities" is a bit awkward. I could say "hereinafter collectively referred to as (new) first-tier cities" or just keep it as is since it' s a definition.

"Using relevant indicators and data, we analyze their participation in research frontiers to provide data references for scientific research and development in various cities and enrich research on urban innovation capacity [50-56]."

Good closing sentence.

Now let me put it all together, ensuring smooth flow and academic tone.

I notice the text has some run-on sentences and could be structured better. Let me reorganize slightly for better readability while preserving all meaning and citations.

Original structure: 1. Science/tech importance and urban development link 2. Current frontier research is discipline-specific [1-22], emphasizing theoretical 梳理 3. Science and Technology Daily column on chokepoint tech [23] 4. Global reports exist [24,25,29] 5. But participation in frontiers is scarce due to definitional difficulties 6. Bibliometric data enables progress 7. Current frontier research includes CAS/CAE reports and Elsevier indicators [30-42] 8. Related interpretations [43] and limited analyses [44-49] exist 9. This paper uses their data to study China and cities' participation 10. Selects 4 first-tier + 13 top new first-tier cities 11. Analyzes participation to provide references and enrich urban innovation research [50-56]

I should make this flow better. Let me try:

Paragraph 1: Opening about science/tech and urban development Paragraph 2: Current state of frontier research (discipline-specific, theoretical focus, examples) Paragraph 3: Gap in participation research, but data sources now available Paragraph 4: This paper' s contribution and methodology

Let me draft:

1 Introduction

Science and technology constitute the core of modern national competition and development, having become a country' s key competitive advantage, while urban development has always been closely linked to scientific and technological progress. Current research on academic frontiers, apart from total literature in relevant fields, mostly focuses on discipline-specific studies [1-22], emphasizing theoretical systematization. The "Urgently Needed Core Technologies" column in *Science and Technology Daily*' s analysis of 35 Chinese "chokepoint" core technologies [23] proposes directions for scientific research from national social needs. Globally, numerous reports on research frontiers and development trends exist, such as the U.S. report on emerging science and technology trends [24], UNDP' s Development 4.0 [25], and relevant international## 2 Scientific Research Frontiers and Hotspots

The Chinese Academy of Sciences, Chinese Academy of Engineering, and Clarivate Analytics (formerly Thomson Reuters) publish annual reports on natural and social sciences *Research Fronts* and engineering *Global Engineering Fronts*. Each year, they select approximately 150 research frontiers (including over 100 active frontiers and about 50 emerging frontiers) across 11 major disciplines in natural and social sciences, and over 90 global engineering research frontiers and development frontiers in engineering. Both reference Clarivate Analytics' paper and citation data, with expert interpretation (mainly academicians) of research frontiers and priorities, though their methodologies differ in specific details.

For natural and social sciences, starting from 12,147 research frontiers in the ESI database, core papers in each ESI discipline are sorted by total citation frequency, extracting the top 10% of research frontiers. Twenty disciplines (excluding engineering) are integrated into 11 major disciplines, then "youngest" research frontiers are selected based on the average publication year of core papers and adjusted and merged. Key research frontiers are determined based on the (post-2014) average citations per paper per year (CPT) index:

$$CPT = (C/P)/T$$

where C is the number of citing papers (papers citing core papers), P is the number of core papers, and T is the number of years in which citing occurred[1]. When selecting emerging frontiers, greater weight or priority is given to the publication year of core papers, considering only research frontiers with an average core paper publication date after June two years prior.

Engineering frontiers are initially provided by Clarivate Analytics through literature clustering themes and expert nominations of candidate engineering frontiers, then selected through expert evaluation, refinement, surveys, and discussions.

Elsevier' s Scopus database uses topic prominence percentile to measure the development status of research, reflecting disciplinary research heat, which can be queried in its SciVal module. The calculation method for topic prominence is shown in [Figure 1: see original paper], expressed as a percentage where higher values indicate greater impact and attention. Topics are based on literature indexed in Scopus from 1996 to present (covering 95% of documents), clustered into nearly 96,000 research topics based on citation relationships, with similar topics grouped into approximately 1,500 topic clusters. Each article belongs to only one topic and topic cluster[2].

3.1 Natural Science and Social Science Research Frontiers and Participation

(1) Global Natural Science and Social Science Research Frontiers and Emerging Frontiers

From 2013-2021, a total of 868 natural and social science research frontiers were selected. Their word cloud is shown in [Figure 2: see original paper]. The frontiers concentrate in several major areas: 1) disease treatment, especially tumors and cancers, and related molecular mechanisms, cellular processes, and DNA, genomics, and protein pathways; 2) space matter research from neutrinos, fermions, gravitational waves, and dark matter detection to neutron stars and exoplanet observation, astronomical telescope surveys; 3) material preparation from graphene to metals and perovskites, catalysis in processes, composites and their applications in electrodes and superconductivity; 4) basic research related to marine environments, species diversity observation, climate change, and clean energy solutions like solar power; 5) electronic quantum information digital science and algorithms, cryptography, equations, and topological mathematical foundations.

From 2013-2021, 390 emerging frontiers in natural and social sciences were selected, with their word cloud shown in [Figure 3: see original paper]. These emerging frontiers mainly include: 1) COVID-19 and diagnostic testing, vaccine development and viral mechanisms, inhibitors for tumors and leukemia; 2) gravitational wave and dark matter observation; 3) perovskite solar cells, electrode materials, metal disulfides, metal diselenides, iron selenide and other superconducting/insulating materials; 4) catalytic reactions and catalysts, etc.

Since emerging frontiers in various fields do not provide further data with country and institution information, the following analysis focuses only on research frontiers.

(2) National Participation

China is currently the primary producing country of core papers in 101 key frontiers, ranking after the United States (145), United Kingdom (106), and Germany (103), as shown in [Figure 4: see original paper]. Based on the latest data, China' s number of contributed key frontiers has surpassed the United States, becoming the country with the most globally [Figure 5: see original paper].

China is also the primary citing country of core papers in 140 key frontiers, ranking after the United States (161), United Kingdom (150), and Germany (149), as shown in [Figure 6: see original paper]. According to the latest data, China' s number of participated key frontiers has exceeded Germany, ranking third globally [Figure 7: see original paper].

(3) (New) First-Tier City Participation

From 2013-2021, the cumulative frequency of domestic city institutions and the Chinese Academy of Sciences (CAS)[2] being primary producing institutions of core papers in key frontiers[3] is 259. Beijing institutions have the highest cumulative frequency at 63, followed by CAS (44), then Hong Kong, Shanghai, Wuhan, and Nanjing (with cumulative frequencies of 19, 19, 17, and 13 respectively), as detailed in .

From 2013-2021, China demonstrates more prominent leadership in mathematics/computer science and engineering, chemistry and materials science, physics, and earth sciences. Among (new) first-tier cities, Beijing shows outstanding performance in mathematics/computer science and engineering, earth sciences, chemistry and materials science, agricultural sciences/plant and animal sciences, physics, and biological sciences. Nanjing excels in mathematics/computer science and engineering, while Nanjing and Guangzhou show strength in chemistry and materials science, and Wuhan in clinical medicine, as shown in [Figure 8: see original paper]. The mean proportion of core papers from city institutions across fields reflects the prominence of institutions leading global research in that disciplinary area, with higher values indicating stronger leadership. [Figure 9: see original paper] shows that Beijing, Wuhan, Nanjing, Shanghai, and Xi' an demonstrate strong leadership across natural and social science fields, while Tianjin, Shenzhen, and Guangzhou only show prominent leadership in one or two disciplines.

From 2013-2021, the cumulative frequency of domestic city institutions and CAS being primary citing institutions of core papers in key frontiers is 390. CAS has the highest cumulative frequency at 101, followed by Beijing (92), then Nanjing, Wuhan, Shanghai, and Hangzhou (with cumulative frequencies of 26, 23, 21, and 17 respectively), as detailed in .

From 2013-2021, China shows greatest attention (largest number of citing papers for frontier core papers) in chemistry and materials science, mathematics/computer science and engineering, earth sciences, physics, and ecological and environmental science. Among (new) first-tier cities, Beijing primarily focuses on earth sciences, mathematics/computer science and engineering, chemistry and materials science, ecological and environmental science, physics, and information science; Nanjing on mathematics/computer science and engineering; Wuhan on clinical medicine; and Guangzhou on chemistry and materials science, while other cities show lower attention to frontier core papers, as shown in [Figure 10: see original paper]. [Figure 11: see original paper] indicates that Nanjing, Beijing, Wuhan, Xi' an, Shanghai, Hangzhou, Guangzhou, and Chengdu follow developments across various natural and social science fields with relatively balanced disciplinary distribution and large citing proportions, while Qingdao, Shenzhen, and Chongqing concentrate in only one or two disciplines.

Combining data from Tables 1 and 2 shows that Chinese institutions' participation in natural and social science frontier research is better than their leadership, with recent years showing improving performance in both leading and participating in frontier research.

In summary, China' s and its cities' participation generally exceeds their leadership. Nationally, China' s performance in frontier research has improved rapidly, approaching that of the United States, which has the best frontier participation. At the city level, Beijing significantly outperforms other cities, with Shanghai, Wuhan, Nanjing, Hangzhou, Xi' an, and others following closely in natural sciences, while Shanghai, Wuhan, Nanjing, Changsha, and Xi' an follow in engineering technology, and Shanghai, Guangzhou, Shenzhen, Chengdu, and Hangzhou show good performance in engineering development. Other cities' performance is less prominent.

3.2 Engineering Research Frontiers and Participation

(1) Engineering Research Frontiers

Global Engineering Research Frontiers From 2017-2021, 461 engineering research frontiers were selected, with their word cloud shown in [Figure 12: see original paper]. Engineering frontier research concentrates in: 1) various functional materials, catalysts, electrodes, biomedical materials, nanomodification, and composites; 2) electronic information digital science including big data, blockchain, artificial intelligence, sharing economy, robotics, and chips; 3) clean energy such as solar, hydrogen, and nuclear power, energy storage equipment, climate change, and environmental pollution; 4) soil fungi, breeding, and agriculture; 5) tumor immunology/targeted therapy, medical big data, etc.

National Participation China is currently the primary producing country of core papers in 129 key frontiers, ranking after the United States (136), as shown in [Figure 13: see original paper]. Based on the latest data, China' s number of contributed key frontiers has equaled the United States, both being the most globally [Figure 14: see original paper].

China is the primary citing country of core papers in 117 key frontiers, fewer than the United States (121) but more than the United Kingdom (110) and Australia (89), as shown in [Figure 15: see original paper]. The latest data shows China is accelerating its participation in key frontiers [Figure 16: see original paper].

(New) First-Tier City Participation The cumulative frequency of city institutions and CAS being primary producing institutions of core papers in key frontier research is 348. Beijing institutions have the highest cumulative frequency at 64, followed by CAS (54), then Shanghai, Hong Kong, Wuhan, Nanjing, and Xi' an (with cumulative frequencies of 33, 22, 20, 19, and 19 respectively), as detailed in .

From 2017-2021, China demonstrates more prominent leadership in chemical/metallurgical and materials engineering, medicine and health, environmental and light textile engineering, and information and electronic engineering, with many core papers and high impact, as shown in [Figure 17: see original paper] and [Figure 18: see original paper]. Among (new) first-tier cities, Beijing shows outstanding performance in chemical/metallurgical and materials engineering, environmental and light textile engineering, information and electronic engineering, and energy and mining engineering; Shanghai in medicine and health, chemical/metallurgical and materials engineering, and environmental and light textile engineering; Wuhan in medicine and health, civil/hydraulic and architectural engineering, and energy and mining engineering; Xi' an in chemical/metallurgical and materials engineering and energy and mining engineering; Nanjing in information and electronic engineering; Changsha in mechanical and transportation engineering; Hangzhou and Suzhou in chemical/metallurgical and materials engineering; and Chengdu in information and electronic engineering, as detailed in [Figure 19: see original paper]. Beijing and Wuhan' s medicine and health, Xi' an' s chemical/metallurgical and materials engineering, Chengdu' s information and electronic engineering, Guangzhou and Zhengzhou' s environmental and light textile engineering, and Changsha' s civil/hydraulic and architectural engineering show prominent citation performance for core papers, as shown in [Figure 18: see original paper]. [Figure 19: see original paper] shows that Nanjing, Changsha, Beijing, Shanghai, Xi' an, and Wuhan demonstrate good leadership across various engineering fields, while Suzhou, Chengdu, Tianjin, Chongqing, Qingdao, and Hangzhou concentrate their leadership in one or two fields.

Among (new) first-tier cities, there are 43 highly cited papers (top 10% globally in citation speed) in core papers (48 nationally) and 2 patent-cited papers (2 nationally).

In engineering frontier research participation from 2017-2021, the cumulative frequency of domestic city institutions and CAS being primary citing institutions of core papers in key frontier research is 521. Beijing institutions have the highest cumulative frequency at 115, followed by CAS (74), then Shanghai, Wuhan, Nanjing, and Xi' an (with cumulative frequencies of 46, 39, 29, and 26 respectively), as detailed in .

From 2017-2021, China participates more actively in frontier research in chemical/metallurgical and materials engineering, energy and mining engineering, environmental and light textile engineering, and agriculture, with many citing core papers and large proportions, as shown in [Figure 20: see original paper] and [Figure 21: see original paper]. Among (new) first-tier cities, Beijing, Wuhan, Shanghai, Hangzhou, and Suzhou participate in chemical/metallurgical and materials engineering frontier research, with Beijing also extensively following frontier research in energy and mining engineering, information and electronic engineering, environmental and light textile engineering, and agriculture. [Figure 21: see original paper] shows that Changsha, Shanghai, Beijing, Guangzhou, Xi' an, Wuhan, Tianjin, and Hangzhou demonstrate good momentum in following frontiers across various engineering fields, while Shenyang, Suzhou, and Qingdao concentrate their frontier-following momentum in one or two fields.

Combining data from Tables 3 and 4 shows that Chinese institutions' participation in engineering frontier research exceeds their leadership, with recent years showing improving performance in both leading and participating in frontier research.

(2) Engineering Development Frontiers

Global Engineering Development Frontiers From 2017-2021, 450 development frontiers were selected, with their word cloud shown in [Figure 22: see original paper]. Engineering frontier development primarily focuses on intelligence, concentrated in: 1) intelligent manufacturing and precision processing; 2) aircraft, robotics, unmanned driving, wearable devices, and related control technology and sensors; 3) healthcare and medicine supported by health big data; 4) intelligent city management; 5) imaging technology and image recognition. Additionally, there is notable concentration on battery research.

National Participation China is currently the primary producing country of core patents in 134 key development frontiers, more than the United States (130), as shown in [Figure 23: see original paper]. Based on the latest data, China' s number of development frontiers has equaled the United States, both being the most globally [Figure 24: see original paper].

(New) First-Tier City Participation In engineering development frontier attention from 2017-2021, the cumulative frequency of domestic city institutions being primary producing institutions of core patents in key engineering development frontiers is 487 (incomplete statistics[1]). Beijing institutions have the highest cumulative frequency at 104, followed by Shanghai (26), then Guangzhou, Shenzhen, Chengdu, Hangzhou, and Nanjing (with cumulative frequencies of 23, 22, 20, 20, and 20 respectively), as detailed in .

From 2017-2021, China has more core patents in energy and mining engineering, medicine and health, chemical/metallurgical and materials engineering, environmental and light textile engineering, and mechanical and transportation engineering, with outstanding performance in industrial management influence but insufficient performance in medicine and health, as shown in [Figure 25: see original paper] and [Figure 26: see original paper]. Among (new) first-tier cities, Beijing, Guangzhou, Hangzhou, Shanghai, Nanjing, Chengdu, Shenzhen, and Tianjin show good overall performance. Specifically, Beijing demonstrates outstanding performance in energy and mining engineering, medicine and health, chemical/metallurgical and materials engineering, environmental and light textile engineering, information and electronic engineering, and civil/hydraulic and architectural engineering; Guangzhou, Hangzhou, Shanghai, and Tianjin in engineering management; Shenzhen in mechanical and transportation engineering; Shanghai in chemical/metallurgical and materials engineering; and Hangzhou in energy and mining engineering. [Figure 27: see original paper] shows that Dongguan, Chengdu, Beijing, Guangzhou, and Chongqing have higher proportions of core patents among their patents.

(3) Summary

Research frontier data shows that China' s participation in natural science and engineering frontier research has progressed rapidly, gradually demonstrating a status corresponding to its research output[1]. Overall, frontier research participation institutions are distributed in a limited number of cities, mainly coastal cities (see [Figure 28: see original paper]). In terms of city performance, Beijing' s performance is particularly outstanding, with Shanghai, Wuhan, Nanjing, Hangzhou, and Xi' an following closely in natural sciences, while Shanghai, Wuhan, Nanjing, Changsha, and Xi' an follow in engineering technology, and Guangzhou, Shenzhen, Chengdu, and Hangzhou also show good performance in engineering development.

Regarding specific fields, China and (new) first-tier cities demonstrate good leadership and followership in mathematics/computer science and engineering, chemistry/chemical engineering and materials science, physics, earth sciences, ecology/environmental science and engineering, biological/agricultural science and engineering, and energy and mining engineering. Fields with better leadership also include medicine and health, information and electronic engineering, while mechanical and transportation engineering and engineering management show good frontier-following performance[2].

4.1 Hot Topics

(1) Hot Topics and Topic Clusters

Elsevier' s SciVal database clusters global scientific research into 95,921 topics belonging to 1,495 topic clusters. Our subsequent research primarily focuses on the top 1,000 topics globally by prominence (covering topics above 98.9590% prominence, accounting for 1.0426% of global topics) and the top 10% of topic clusters (150 clusters, accounting for 10.0333% of global topic clusters).

The word cloud for the top 1,000 topics globally by prominence is shown in [Figure 29: see original paper], and for the top 10% of topic clusters in [Figure 30: see original paper]. The figures show that frontier research concentrates in biology and medical health (COVID-19, cancer, tumors, inflammation, DNA, proteins, genetic programming, genes, tissue engineering, etc.), energy (including storage) and climate (electrode materials, ion storage, electrocatalysts, catalysts, nanocrystals, biofuels, batteries, climate change, sustainability, carbon, adsorption, nitrogen removal, wastewater treatment, China, etc.), information technology and artificial intelligence (Internet of Things, topological structures, neural networks, convolutional neural networks, deep learning, etc.), and social research (social media, innovation, networks, corporate social responsibility, community participation, etc.).

(2) National Participation in Topic Clusters and Topics

During the 2011-2020 data window, the top 21 countries/regions contributed over 80% of global academic output, as shown in [Figure 31: see original paper]. China, the United States, and the United Kingdom lead, contributing over 38%.

China, the United States, and the United Kingdom cover all topic clusters with prominence above 90%. In these clusters, China' s contribution rate is 21.70%, the United States 22.56%, and the United Kingdom 6.69%, but China's influence is 1.1755, lower than both the U.S. and U.K., as shown in [Figure 32: see original paper].

All three countries cover 974 of the top 1,000 topics by global prominence. Among these topics, China' s contribution rate is 26.78%, the United States 22.80%, and the United Kingdom 6.54%, but China' s influence is 1.8581, lower than both the U.S. and U.K., as shown in [Figure 33: see original paper].

(3) (New) First-Tier City Participation in Hot Topic Clusters

During the 2011-2020 data window, the distribution of prominence (prominence percentage), contribution (paper share in topics), and influence (FWCI) for the 500 topic clusters with the largest paper shares across disciplines in (new) first-tier cities is shown in [Figure 34: see original paper]-[Figure 36: see original paper]. Overall, Beijing, Guangzhou, and Shanghai are cities with high contribution, good prominence, and strong influence. Shenzhen, Wuhan, and Hangzhou have relatively large contributions and excellent prominence, though Wuhan and Hangzhou have average influence while Shenzhen' s influence is relatively small. Xi' an shows poor prominence, unremarkable contribution, and low influence, while Dongguan has not yet fully developed in contribution, prominence, and influence.

During the 2011-2020 data window, the 500 topic clusters with the largest paper shares across disciplines in (new) first-tier cities fully cover frontier topic clusters (top 10% globally by prominence). Specifically, except for Dongguan which covers only 91.33% of topic clusters (137 clusters), all other cities achieve full coverage of the top 10% of topic clusters.

Cities with the largest contribution to covered frontier topics are Beijing, Shanghai, Nanjing, Guangzhou, and Wuhan, while those with the smallest contribution are Dongguan, Suzhou, Shenzhen, Zhengzhou, and Qingdao. In terms of influence on covered frontiers, the most influential are Shenzhen, Hangzhou, Shanghai, Beijing, and Wuhan, as shown in [Figure 37: see original paper].

Global topic clusters are mainly distributed in engineering, medicine, materials, chemistry, computer science, and other disciplines, as shown in [Figure 38: see original paper]. The disciplinary distribution of topic clusters across cities shows no significant difference, as shown in [Figure 39: see original paper]. The contribution and influence of covered top 10% topic clusters across cities are shown in [Figure 40: see original paper] and [Figure 41: see original paper].

(4) (New) First-Tier City Participation in Hot Topics

During the 2011-2020 data window, the distribution of prominence, contribution, and influence for the 500 topics with the most papers across disciplines in (new) first-tier cities is shown in [Figure 42: see original paper]-[Figure 44: see original paper]. Overall, Beijing has high contribution, better prominence, and strong influence. Shenzhen and Dongguan have relatively small contributions but excellent prominence, though Shenzhen' s influence is significantly better than Dongguan' s. Shenyang, Chongqing, Chengdu, Changsha, and others have unremarkable prominence, contribution, and influence.

During the 2011-2020 data window, the 500 topics with the most papers across disciplines in (new) first-tier cities cover 968 of the top 1,000 topics globally by prominence, with coverage of the vast majority of topics. Specifically, cities with the largest coverage are Shanghai, Beijing, Guangzhou, Wuhan, and Nanjing, while those with the smallest coverage are Dongguan, Qingdao, Suzhou, Shenyang, and Zhengzhou, as shown in [Figure 45: see original paper].

Cities with the largest contribution to covered frontier topics are Beijing, Shanghai, Nanjing, Guangzhou, and Wuhan, while those with the smallest contribution are Dongguan, Suzhou, Zhengzhou, Qingdao, and Shenzhen. In terms of influence on covered frontiers, the most influential are Shenzhen, Wuhan, Hangzhou, Shanghai, and Beijing, as shown in [Figure 46: see original paper].

Among the 500 topics with the most papers across disciplines in (new) first-tier cities, the top 1,000 topics globally by prominence are most heavily distributed in chemistry, materials science, chemical engineering, engineering, physics and astronomy, followed by energy, biochemistry/genetics and molecular biology, environmental science, computer science, and medicine. Compared with the global disciplinary distribution of top 1,000 topics by prominence (see [Figure 47: see original paper]), (new) first-tier cities still underperform in engineering, biochemistry/genetics and molecular biology, and medicine, which have large global frontier distributions. The disciplinary distribution across cities is largely consistent, as shown in [Figure 48: see original paper].

The contribution and influence of covered frontiers vary by discipline across cities, with greater contribution in materials science, chemistry, engineering, physics and astronomy, and chemical engineering, and greater influence in veterinary medicine, dentistry, immunology and microbiology, engineering, physics and astronomy, and chemical engineering. The contribution and influence of covered frontier disciplines across cities are detailed in [Figure 49: see original paper] and [Figure 50: see original paper].

Overall, in terms of city performance, Beijing is very prominent in contribution and influence in frontier fields, while Guangzhou, Shanghai, Nanjing, and Wuhan are cities with good performance in prominence, contribution, and influence. Although Dongguan, Suzhou, and Zhengzhou currently have small overall influence and insufficient contribution, the topics they dominate show excellent prominence. Shenzhen, while having excellent prominence, has gradually developed its influence. Particularly, Shenyang shows outstanding prominence in frontier research during its transformation and strengthening as an old industrial base. Other cities are not particularly prominent in prominence, contribution, and influence.

In terms of field distribution, within the global frontier topic disciplinary structure, (new) first-tier cities still underperform in engineering, biochemistry/genetics and molecular biology, and medicine, which have large global frontier distributions. Frontier topics are distributed in relatively traditional disciplines such as chemistry, chemical engineering, energy, materials science, and medicine, but except for medicine, influence is generally small.

5 Research Conclusions

During China’ s rapid comprehensive national power enhancement, its participation in global academic research frontiers has improved tremendously. This improvement is evident not only in the quantity of academic output but also, as this study demonstrates, in participation in academic frontier fields, gradually demonstrating a status corresponding to research output, though research levels still require significant improvement. Overall, China has approached the United States, which has the best frontier participation. However, in terms of development momentum in frontier and hotspot research, China and its cities generally participate and follow more than they lead.

In terms of field distribution, China and (new) first-tier cities show better leadership and followership in mathematics/computer science and engineering, chemistry/chemical engineering and materials science, physics, earth sciences, ecology/environmental science and engineering, biological/agricultural science and engineering, and energy and mining engineering. Overall, frontier research participation in engineering and technology fields outperforms that in natural sciences. In terms of disciplinary distribution, frontier topics in (new) first-tier cities are distributed in relatively traditional disciplines such as chemistry, chemical engineering, energy, materials science, and medicine, but except for medicine, influence is generally small. There remains a gap in performance in globally frontier-distributed disciplines such as engineering, biochemistry/genetics and molecular biology, and medicine.

In terms of geographical and city distribution, Chinese institutions participating in global academic frontiers are distributed in a limited number of cities, mainly coastal cities, with relatively poorer participation from inland cities. Research frontier data shows Beijing’ s performance is particularly outstanding, with Shanghai, Nanjing, Wuhan, and Guangzhou performing well, and Hangzhou showing good performance in natural science research while Xi’ an excels in engineering technology research. Other cities are less prominent in frontier research participation and performance. Topic frontier data shows Beijing and CAS perform very outstandingly, followed by Guangzhou, Shanghai, Nanjing, and Wuhan among (new) first-tier cities. Dongguan, Suzhou, Zhengzhou, Shenzhen, and Shenyang, whether as late-developing or reform cities, show very prominent performance in research prominence. Particularly, Shenzhen, despite limited overall contribution, has rapidly improved its influence. Other cities show relatively average performance.

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(Corresponding author: Yang Gui E-mail: guiyang@scu.edu.cn)

Author Contributions:
Yang Gui: Conceived research ideas, designed research methodology; organized data; analyzed data; drafted and revised manuscript.
Luo Wenqi, Dai Rui: Revised manuscript.
Xu Zhishu, Huang Qingming, Qi Baichao, Yang Yue, Cao Li: Collected and organized data.

Note: Figure translations are in progress. See original paper for figures.