TRUE NORTH TECHNOLOGIES

IDENTIFYING CANADIAN TECHNOLOGICAL STRENGTHS USING PATENT NETWORK SCIENCE

ANDREW W. TORRANCE, JEVIN D. WEST, & LISA C. FRIEDMAN
KU LAW, MIT SLOAN SCHOOL OF MANAGEMENT, & UW iSCHOOL

DATA AND ANALYSIS COURTESY OF

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The Economist
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Business
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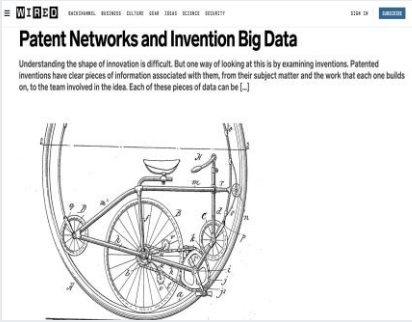
Billion-dollar blueprints
A new way of understanding the high but elusive worth of intellectual property
A group of 65 people have each achieved inventions worth $1bn


WIRED
Patent Networks and Invention Big Data
Understanding the shape of innovation is difficult. But one way of looking at this is by examining inventions. Patented inventions have clear pieces of information associated with them, from their subject matter and the work that each one builds on, to the team involved in the idea. Each of these pieces of data can be [...]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The high value of U.S. patents


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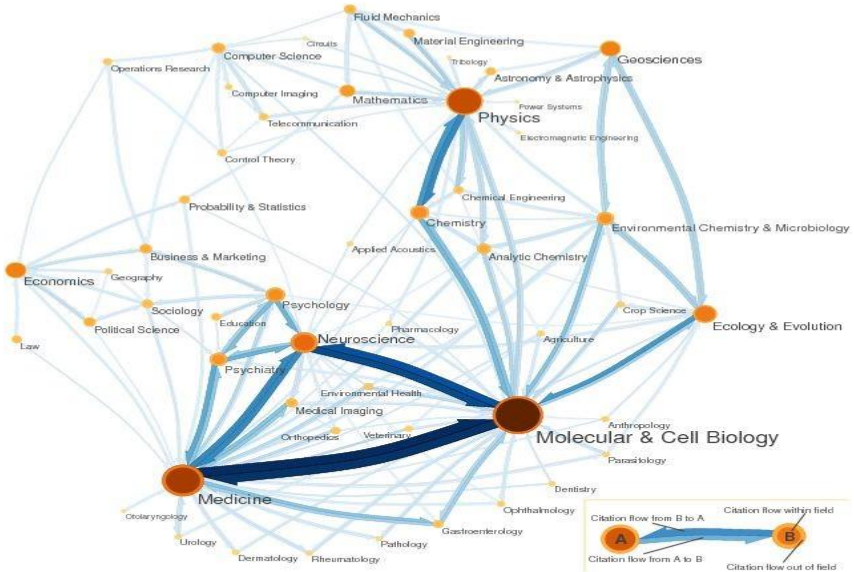
Meet The Guy Who's Got More Patents Than Thomas Edison

FAHRPLAN

- We have now calculated 9 patent citation networks of the worldwide patent system
  - PATSTAT database (Spring and Autumn each year)
    - We owe huge thank you to Geert, Martin, and Johannes at PATSTAT
  - Autumn 2018 to Autumn 2022 (with Spring 2023 almost completed)
- Goals
  - Describe the evolution of the worldwide patent network and highlight Canada's place in this patent network
- Challenges
  - 150 million nodes and 400 million edges
  - Description of static network computationally and interpretationally intensive; describing its evolution is far more challenging
  - Isolating specifically Canadian aspects of network requires special care
- A few observations
  - Interesting changes have been occurring at various depths in the network
  - Flow of information (inferred from citations) among countries is evolving rapidly
  - Canada is one of top patent producers both in volume and importance
  - Largest portfolios of Canadian patents largely owned by non-Canadian firms
  - Canada generally excels at medical devices and is rapidly improving in software and telecommunications
  - Canada is especially strong (sometimes even dominant) in specific technology areas, especially biopharmaceuticals
  - Surprise: Canadian inventions are extremely original!
- Network science is powerful method for gaining insights into worldwide and Canadian patent systems

NETWORK APPROACH

- Related to the *Eigenfactor* metrics
  - Gold standard in ranking scholarly journals
    - *E.g.*, Thomson-Reuters' Journal Citation Reports
- Identify the most important/influential patents in network
- Identify and group patents by concept and technology
- Identify trends
- Can include litigated patents, SEPs, and FDA (Orange and Purple Book) patents
- Search the map of the worldwide patent network like Google Maps



CITATIONS

2017

- Patent citations correlate with patent value/importance
  - Trajtenberg (1989 & 1990)
  - Harhoff et al. (1999)
  - Hall et al (2005)
  - Sampat & Ziedonis (2005)
  - Moser et al. (2011)
  - But see Abrams et al. (2013)
  - *Farranato (2016)*
- **Citations *themselves* differ in importance, so raw citations are misleading**

Farranato (2016)

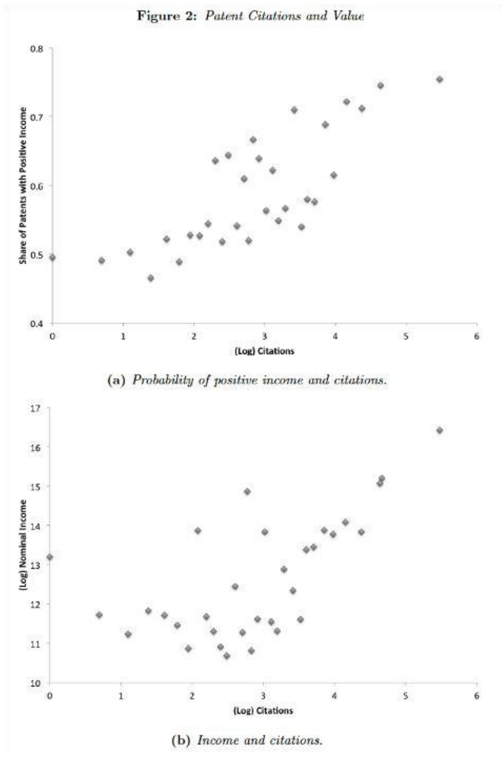


Figure 2: *Patent Citations and Value*

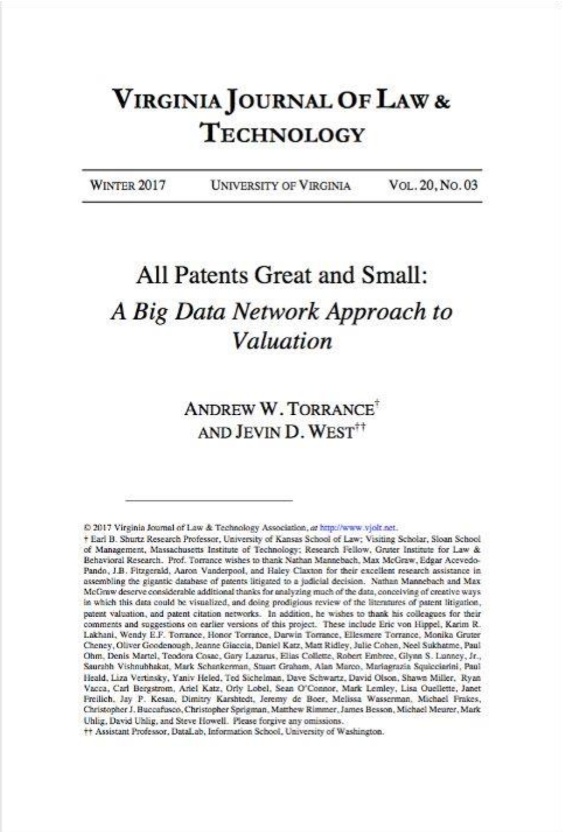
(a) *Probability of positive income and citations.*

(b) *Income and citations.*

NETWORK ANALYTICS

2017

- Connected data may be advantageously analyzed using network science
  - Google, Facebook, LinkedIn
- Patents form a worldwide network
  - Patents are "nodes"
  - Citations are "links"
- Network is built from millions of choices by inventors, owners, and examiners about where inventions belong
- Eigenvector centrality, hierarchical graphing, and community detection methods used to construct comprehensive citation network
- Network structure reveals unique insights
  - Wealth of information about where technology is generated, where it flows, trends, what fields of technology exist, and the importance/influence of patents



VIRGINIA JOURNAL OF LAW & TECHNOLOGY

WINTER 2017 UNIVERSITY OF VIRGINIA VOL. 20, NO. 03

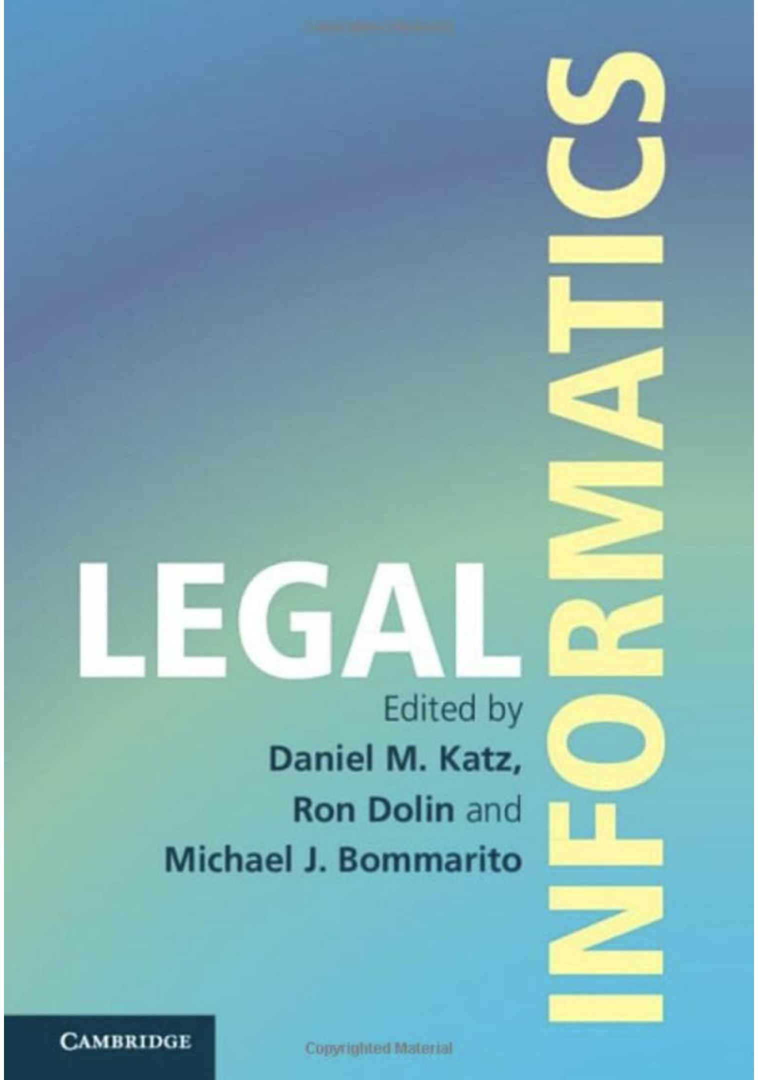
All Patents Great and Small:

A Big Data Network Approach to Valuation

ANDREW W. TORRANCE†
AND JEVIN D. WEST††

† Earl B. Shurtz Research Professor, University of Kansas School of Law; Visiting Scholar, Sloan School of Management, Massachusetts Institute of Technology; Research Fellow, Gruter Institute for Law & Behavioral Research. Prof. Torrance wishes to thank Nathan Mannebach, Max McGraw, Edgar Acevedo-Pando, J.B. Fitzgerald, Aaron Vanderpool, and Haley Claxton for their excellent research assistance in assembling the gigantic database of patents litigated to a judicial decision. Nathan Mannebach and Max McGraw deserve considerable additional thanks for analyzing much of the data, conceiving of creative ways in which this data could be visualized, and doing prodigious review of the literatures of patent litigation, patent valuation, and patent citation networks. In addition, he wishes to thank his colleagues for their comments and suggestions on earlier versions of this project. These include Eric von Hippel, Karim R. Lakhani, Wendy E.F. Torrance, Honor Torrance, Darwin Torrance, Ellesmere Torrance, Monika Gruter Cheney, Oliver Goodenough, Jeanne Giaccia, Daniel Katz, Matt Ridley, Julie Cohen, Neel Sukhatme, Paul Ohm, Denis Martel, Teodora Cosac, Gary Lazarus, Elias Collette, Robert Embree, Glynn S. Lunney, Jr., Saurabh Vishnubhakat, Mark Schankerman, Stuart Graham, Alan Marco, Mariagrazia Squicciarini, Paul Heald, Liza Vertinsky, Yaniv Heled, Ted Sichelman, Dave Schwartz, David Olson, Shawn Miller, Ryan Vacca, Carl Bergstrom, Ariel Katz, Orly Lobel, Sean O'Connor, Mark Lemley, Lisa Ouellette, Janet Freilich, Jay P. Kesan, Dimitry Karshtedt, Jeremy de Boer, Melissa Wasserman, Michael Frakes, Christopher J. Buccafusco, Christopher Sprigman, Matthew Rimmer, James Besson, Michael Meurer, Mark Uhlig, David Uhlig, and Steve Howell. Please forgive any omissions.

†† Assistant Professor, DataLab, Information School, University of Washington.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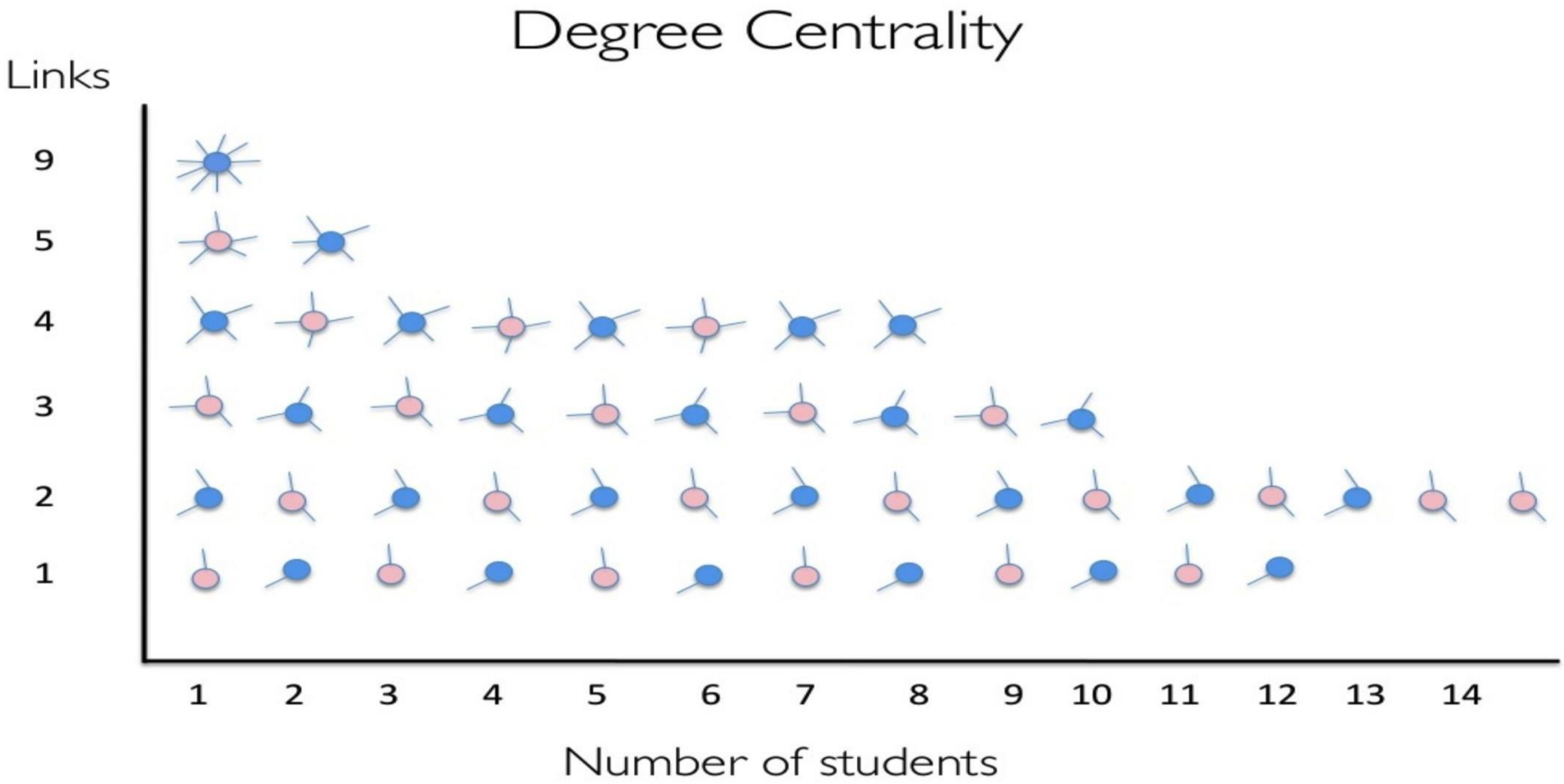
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4
3
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6
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12
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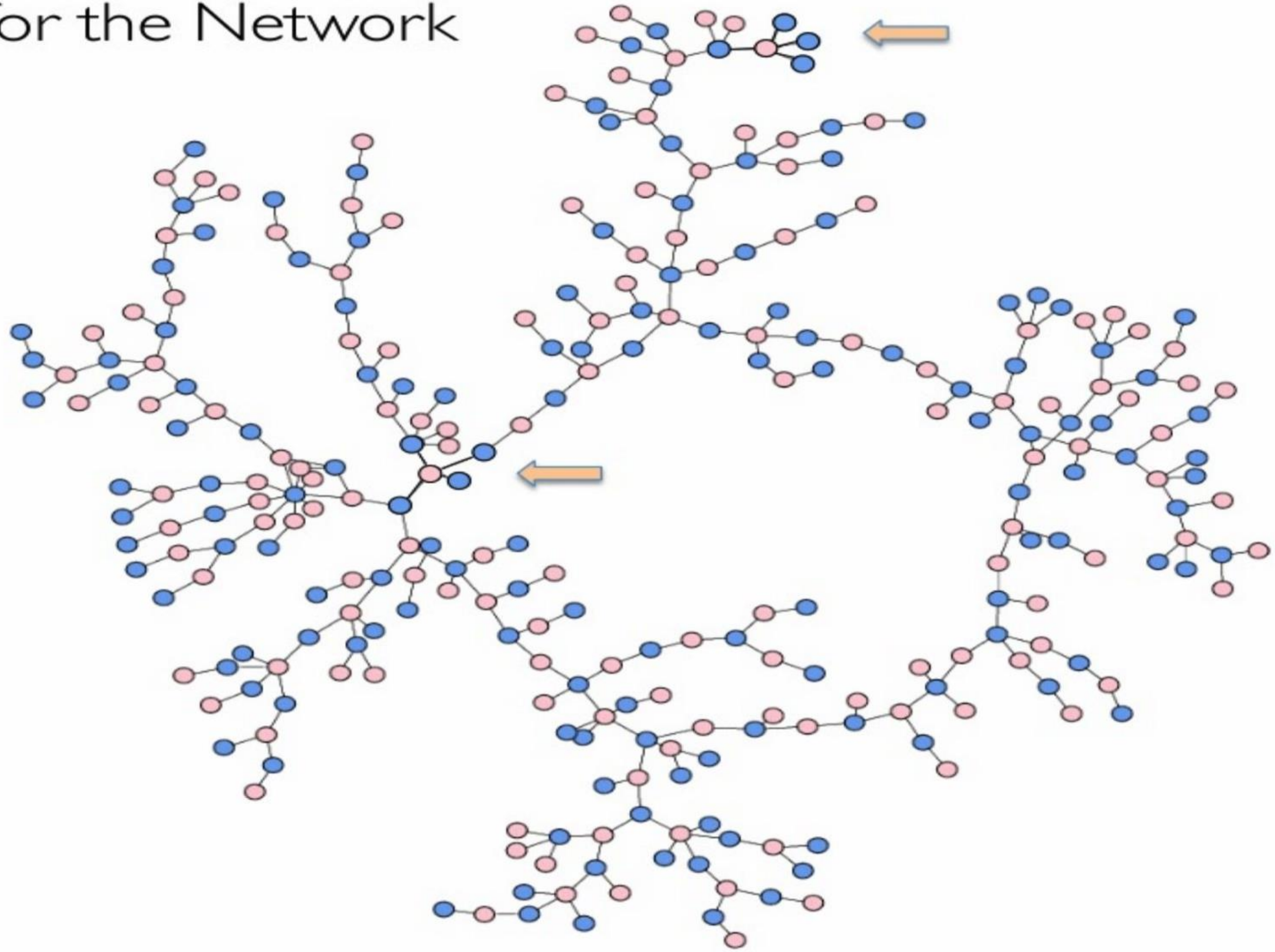
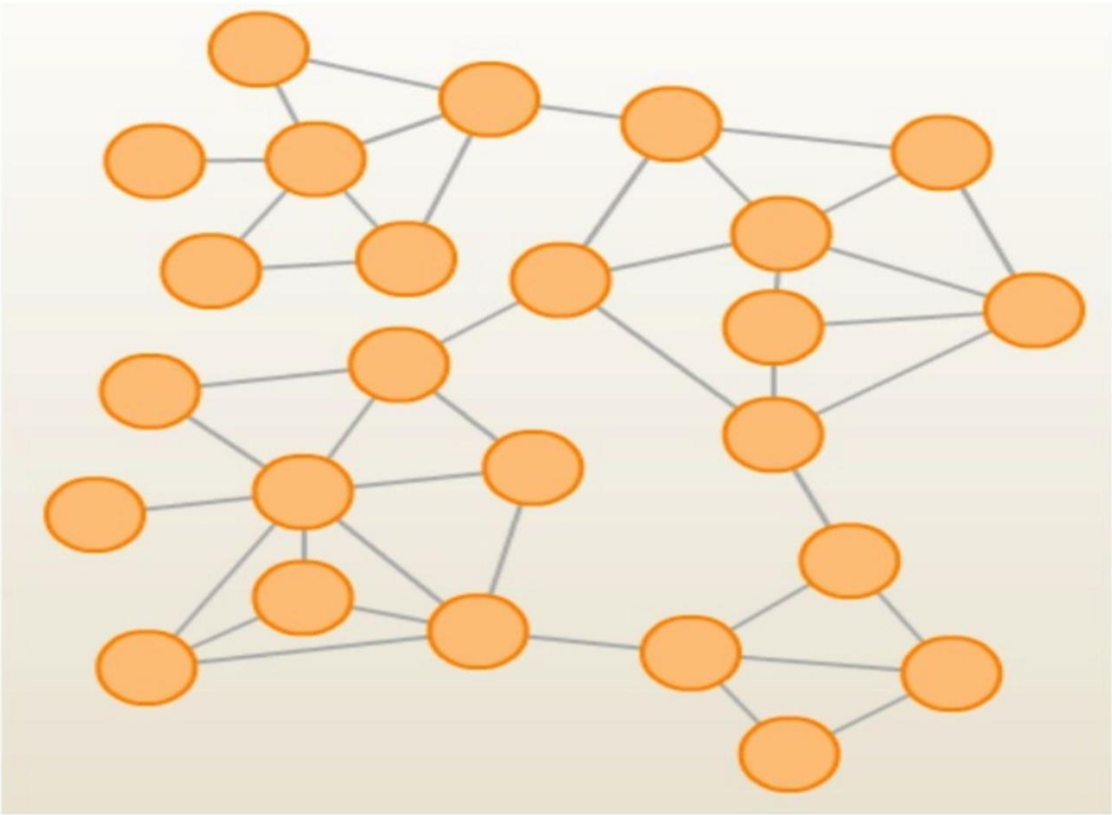
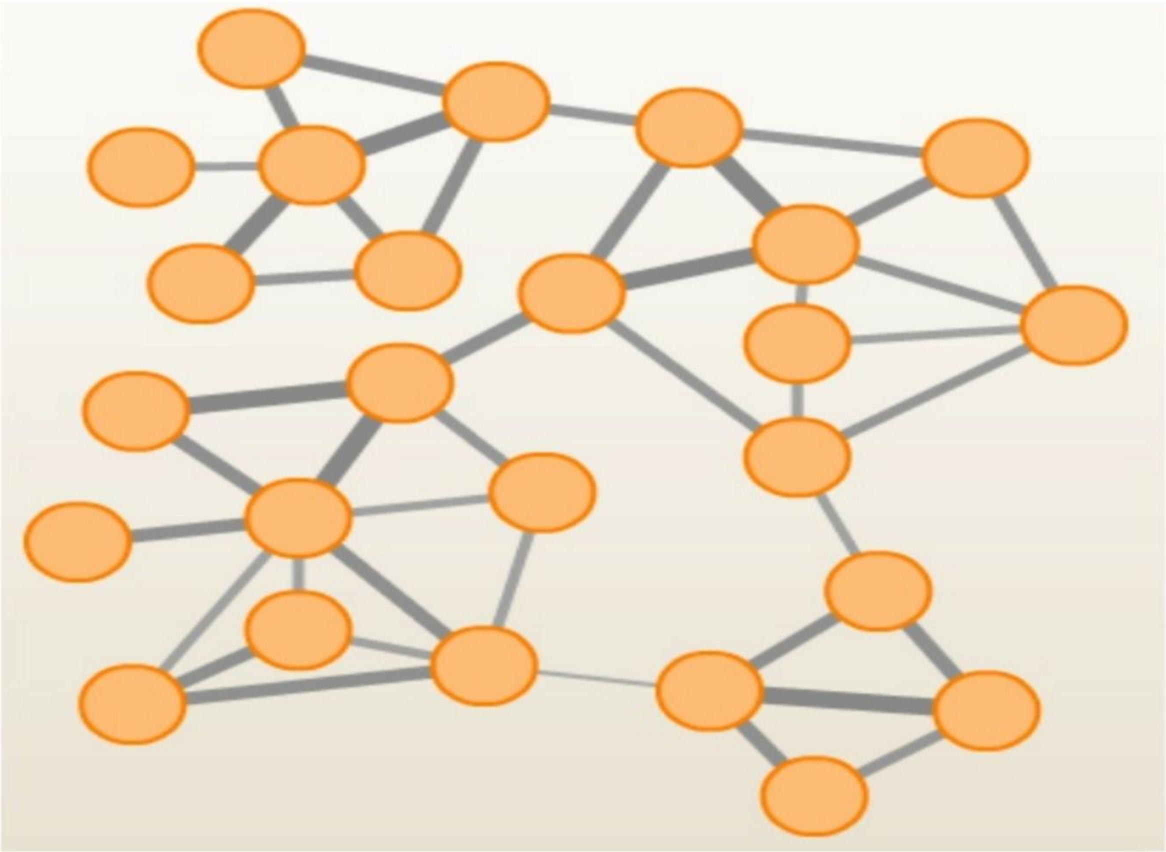
14
Number of students

Accounting for the Network



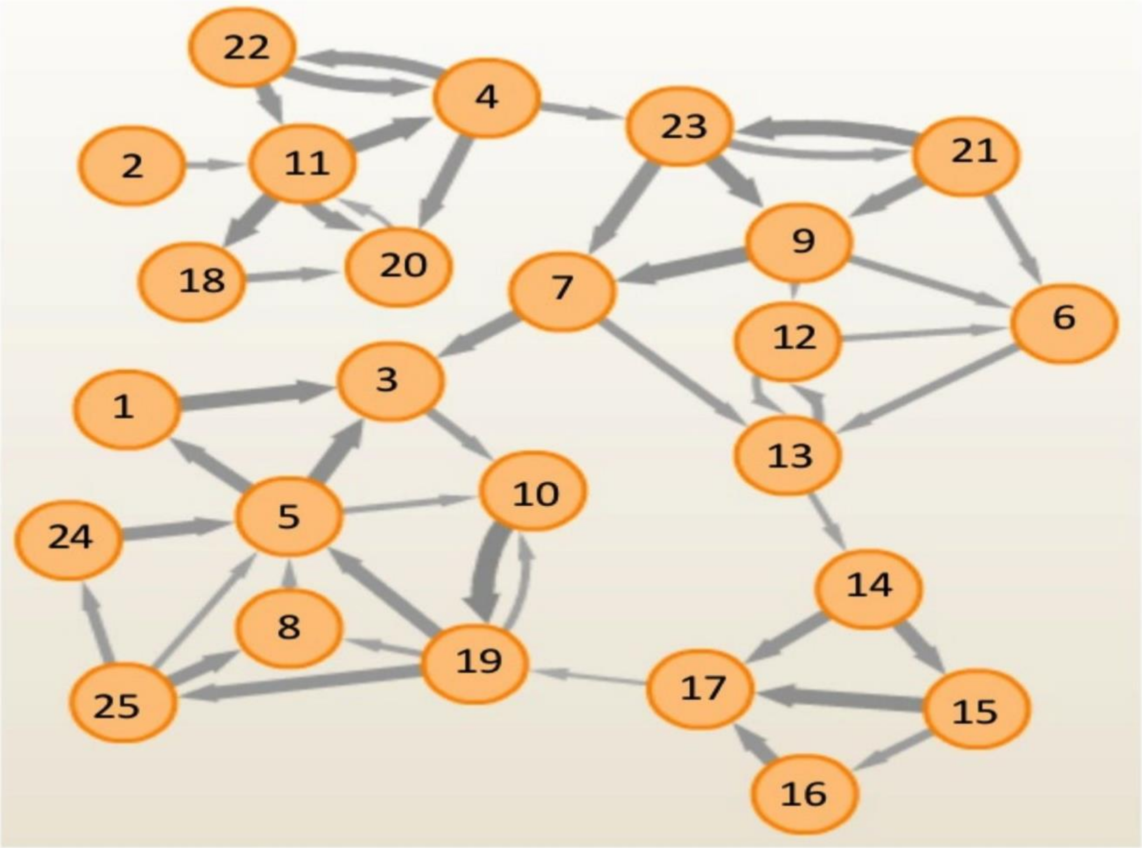


25 nodes and 42 unweighted, undirected links



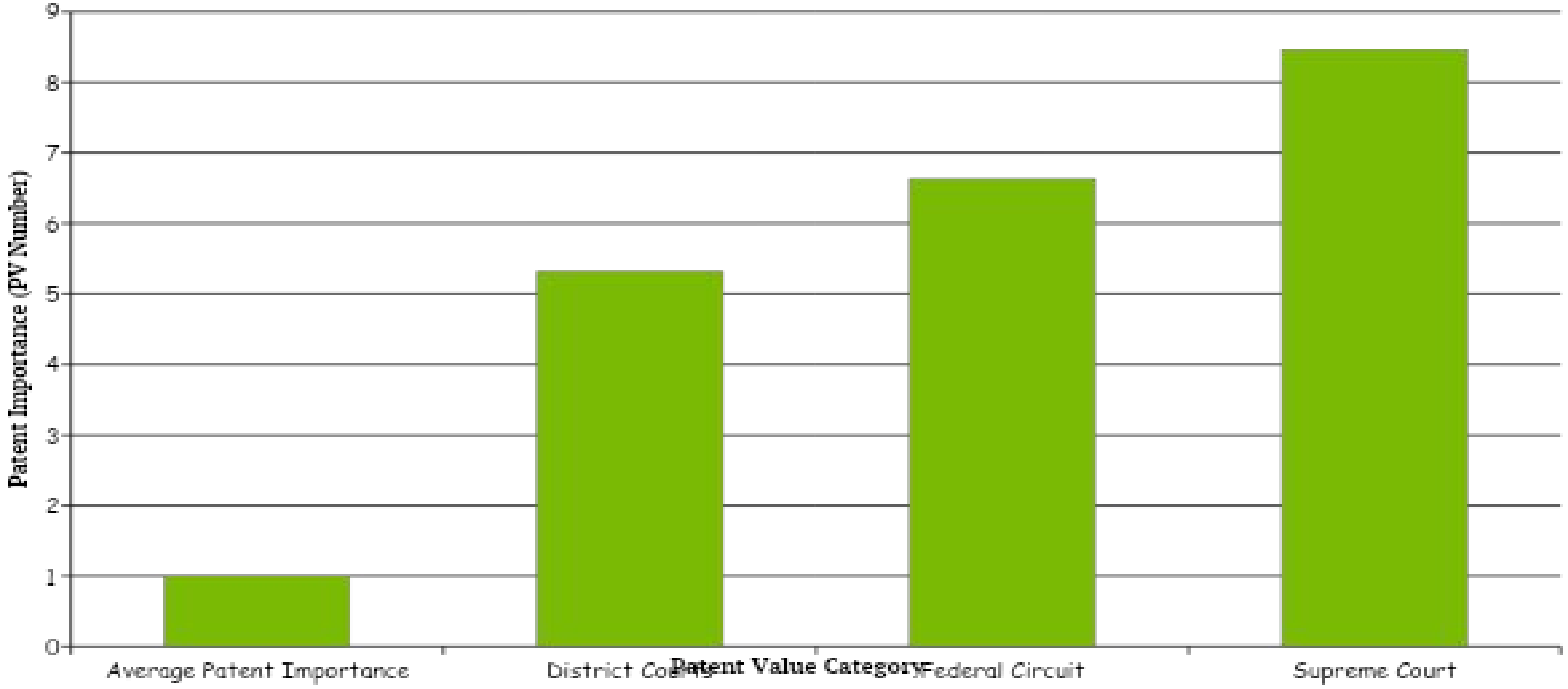
25 nodes and 42 **weighted**, undirected links

Which node is the most central?

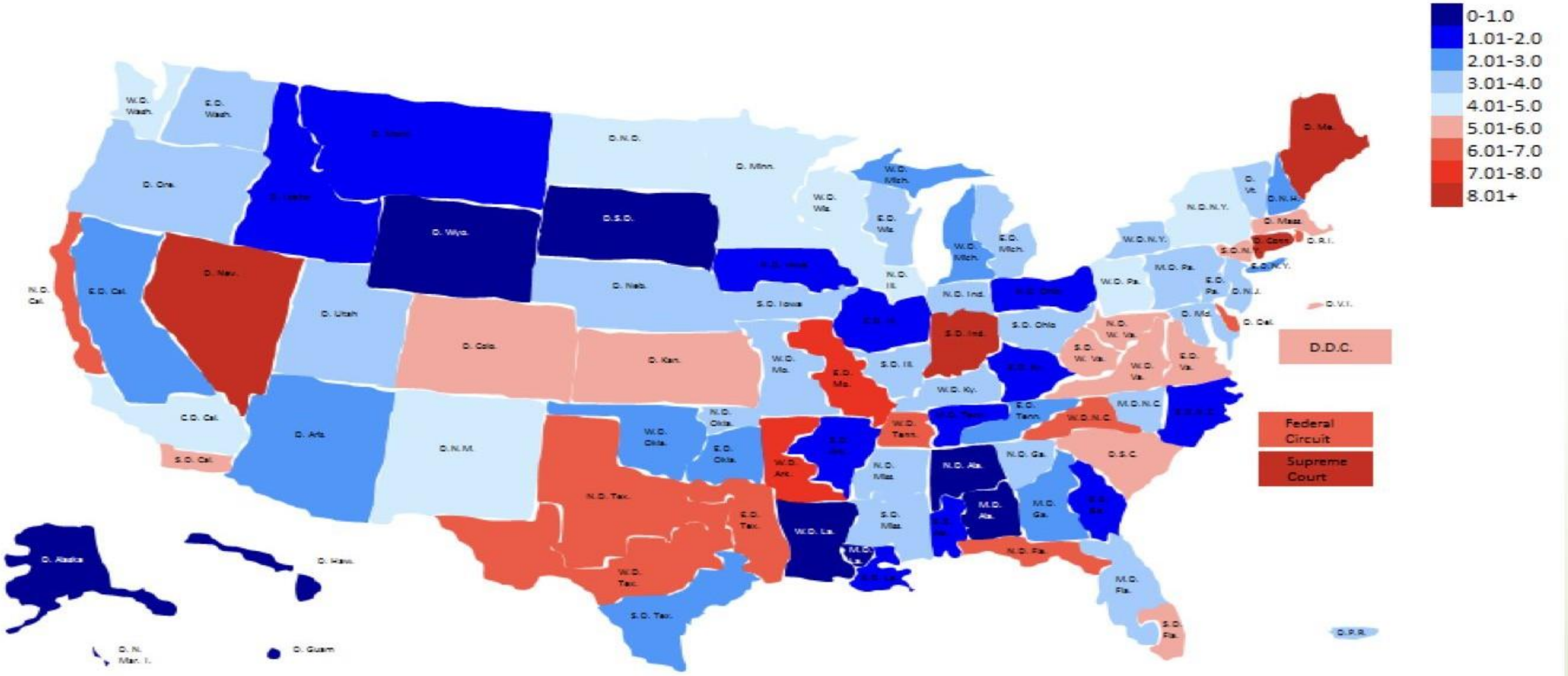


25 nodes and 42 **weighted, directed** links

GOLD STANDARD: LITIGATION

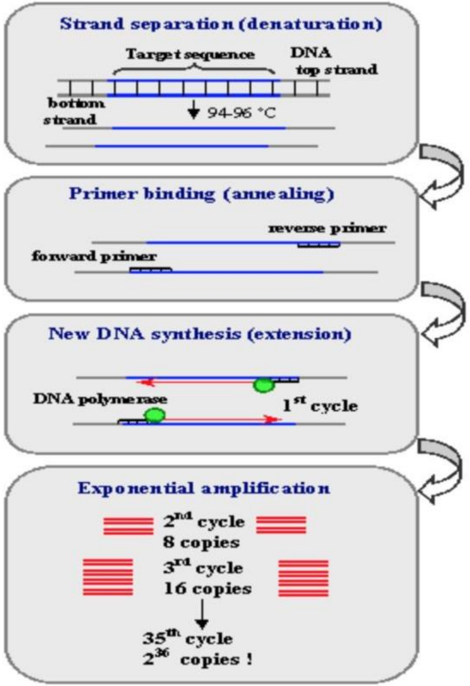


PATENT LITIGATION HEAT MAP



EXAMPLE

- United States Patent Number 4,683,202 is most important patent document in network
- "Process for amplifying nucleic acid sequences"
- Inventor is Kary Mullis
- Has more than 5000 citations
- Is this patent important?
  - Claims a foundational biotechnology
    - NYT: "virtually dividing biology in the two epochs of before P.C.R. and after P.C.R."
  - Mullis shared 1993 Nobel Prize in Chemistry



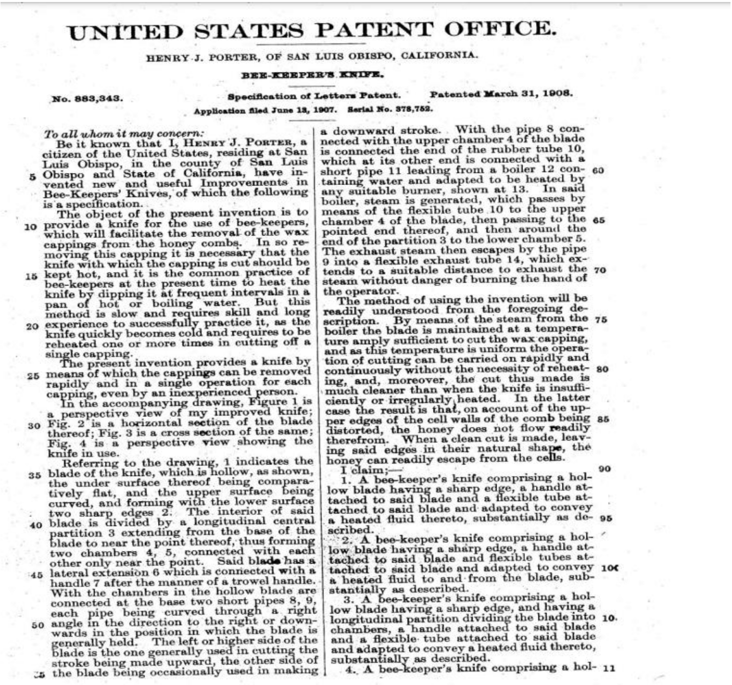
Source: NIH

PATENT DATA

DATABASE	NBER	PATENTVECTOR
TEMPORAL COVERAGE	1963-1999 (or 1976-2006?)	1790-October 2022 (US) +++
JURISDICTIONAL COVERAGE	US	All (~200) patent jurisdictions
NUMBER OF PATENTS	~3 million granted patents	~150 million patents/apps
NUMBER OF CITATIONS	~16 million	~400 million
TECHNOLOGY CATEGORIES	6 major & ~60 minor (artificial)	~31 million (nested & natural)
ASSIGNEES	Compustat (1999) matched	Variations may be combined
INVENTORS	High fidelity	High fidelity
ADDITIONAL DATA	Several additional fields	Many additional fields
RELATED PATENT DATA	None?	Litigation, SEPs, FDA drugs

PARABLE OF THE BEEKEEPER'S KNIFE I

- Micro-heat pipe catheters are a technology area useful in treating hypothermia and cooling patients for surgery
- Involve hollow tubes separated into two separate chambers by an internal septum
- This technology started to develop in the 1980s and 1990s
- Whence did the concept come?



UNITED STATES PATENT OFFICE.

HENRY J. PORTER, OF SAN LUIS OBISPO, CALIFORNIA.

BEE-KEEPER'S KNIFE.

No. 883,343. Specification of Letters Patent. Patented March 31, 1908.

Application filed June 13, 1907. Serial No. 378,752.

To all whom it may concern:

Be it known that I, HENRY J. PORTER, a citizen of the United States, residing at San Luis Obispo, in the county of San Luis Obispo and State of California, have invented new and useful Improvements in Bee-Keepers' Knives, of which the following is a specification.

The object of the present invention is to provide a knife for the use of bee-keepers, which will facilitate the removal of the wax cappings from the honey combs. In so removing this capping it is necessary that the knife with which the capping is cut should be kept hot, and it is the common practice of bee-keepers at the present time to heat the knife by dipping it at frequent intervals in a pan of hot or boiling water. But this method is slow and requires skill and long experience to successfully practice it, as the knife quickly becomes cold and requires to be reheated one or more times in cutting off a single capping.

The present invention provides a knife by means of which the cappings can be removed rapidly and in a single operation for each capping, even by an inexperienced person.

In the accompanying drawing, Figure 1 is a perspective view of my improved knife; Fig. 2 is a horizontal section of the blade thereof; Fig. 3 is a cross section of the same; Fig. 4 is a perspective view showing the knife in use.

Referring to the drawing, 1 indicates the blade of the knife, which is hollow, as shown, the under surface thereof being comparatively flat, and the upper surface being curved, and forming with the lower surface two sharp edges 2. The interior of said blade is divided by a longitudinal central partition 3 extending from the base of the blade to near the point thereof, thus forming two chambers 4, 5, connected with each other only near the point. Said blade has a lateral extension 6 which is connected with a handle 7 after the manner of a trowel handle. With the chambers in the hollow blade are connected at the base two short pipes 8, 9, each pipe being curved through a right angle in the direction to the right or downwards in the position in which the blade is generally held. The left or higher side of the blade is the one generally used in cutting the stroke being made upward, the other side of the blade being occasionally used in making a downward stroke. With the pipe 8 connected with the upper chamber 4 of the blade is connected the end of the rubber tube 10, which at its other end is connected with a short pipe 11 leading from a boiler 12 containing water and adapted to be heated by any suitable burner, shown at 13. In said boiler, steam is generated, which passes by means of the flexible tube 10 to the upper chamber 4 of the blade, then passing to the pointed end thereof, and then around the end of the partition 3 to the lower chamber 5. The exhaust steam then escapes by the pipe 9 into a flexible exhaust tube 14, which extends to a suitable distance to exhaust the steam without danger of burning the hand of the operator.

The method of using the invention will be readily understood from the foregoing description. By means of the steam from the boiler the blade is maintained at a temperature amply sufficient to cut the wax capping, and as this temperature is uniform the operation of cutting can be carried on rapidly and continuously without the necessity of reheating, and, moreover, the cut thus made is much cleaner than when the knife is insufficiently or irregularly heated. In the latter case the result is that, on account of the upper edges of the cell walls of the comb being distorted, the honey does not flow readily therefrom. When a clean cut is made, leaving said edges in their natural shape, the honey can readily escape from the cells.

I claim;—

1. A bee-keeper's knife comprising a hollow blade having a sharp edge, a handle attached to said blade and a flexible tube attached to said blade and adapted to convey a heated fluid thereto, substantially as described.

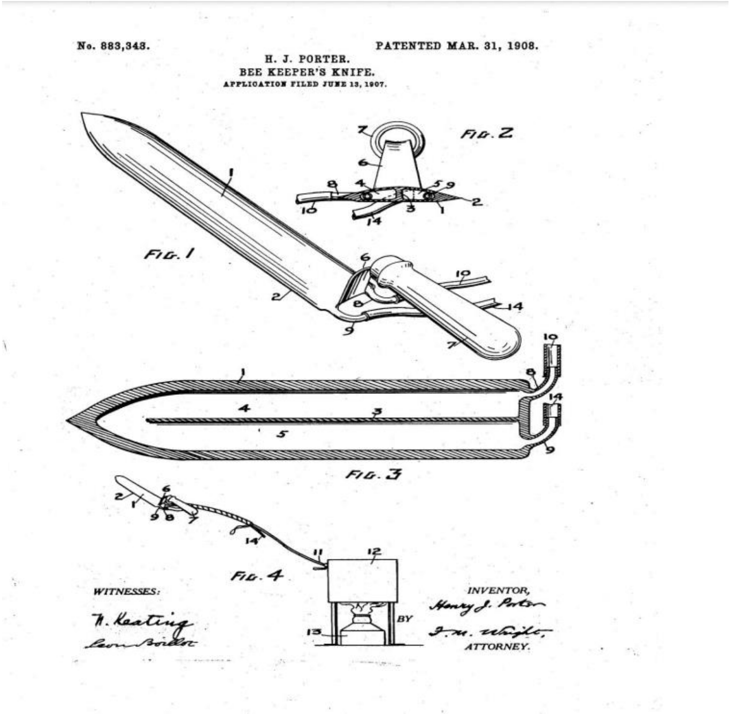
2. A bee-keeper's knife comprising a hollow blade having a sharp edge, a handle attached to said blade and flexible tubes attached to said blade and adapted to convey a heated fluid to and from the blade, substantially as described.

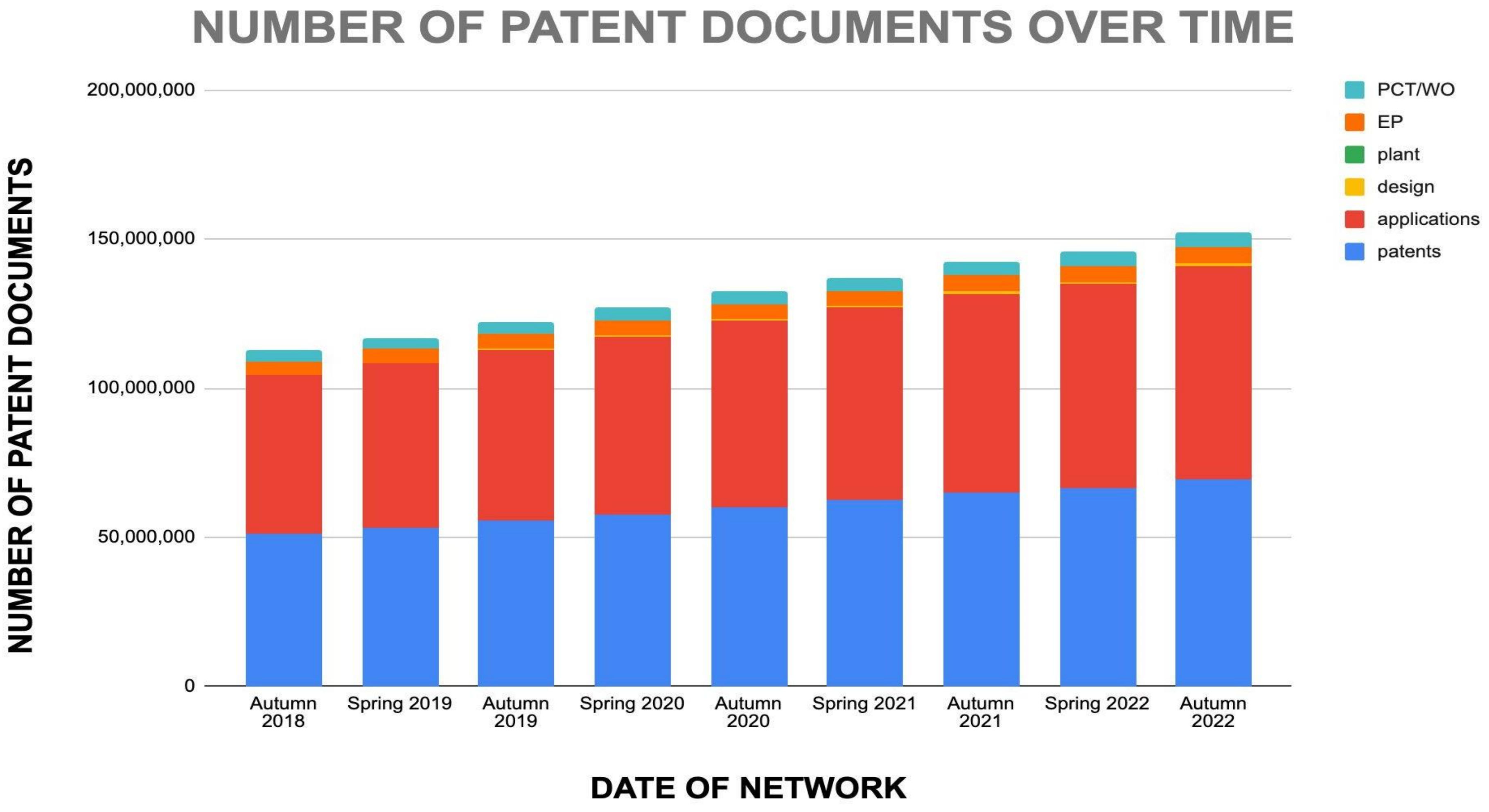
3. A bee-keeper's knife comprising a hollow blade having a sharp edge, and having a longitudinal partition dividing the blade into chambers, a handle attached to said blade and a flexible tube attached to said blade and adapted to convey a heated fluid thereto, substantially as described.

4. A bee-keeper's knife comprising a hol-

PARABLE OF THE BEEKEEPER'S KNIFE II

- Turns out the origin of the technological concept of micro-heat pipe catheters is in the 1908 “Bee Keeper's Knife”
- This invention involves a hollow knife that can be heated by passing hot water through its interior, which is separated by a septum
- WORD QUERIES WILL NOT IDENTIFY THE BEEKEEPER'S KNIFE, BUT NETWORK METHODS AND NEURAL NETWORKS ENSURE THIS PATENT - AND OTHERS - CAN BE LOCATED BY CONCEPT

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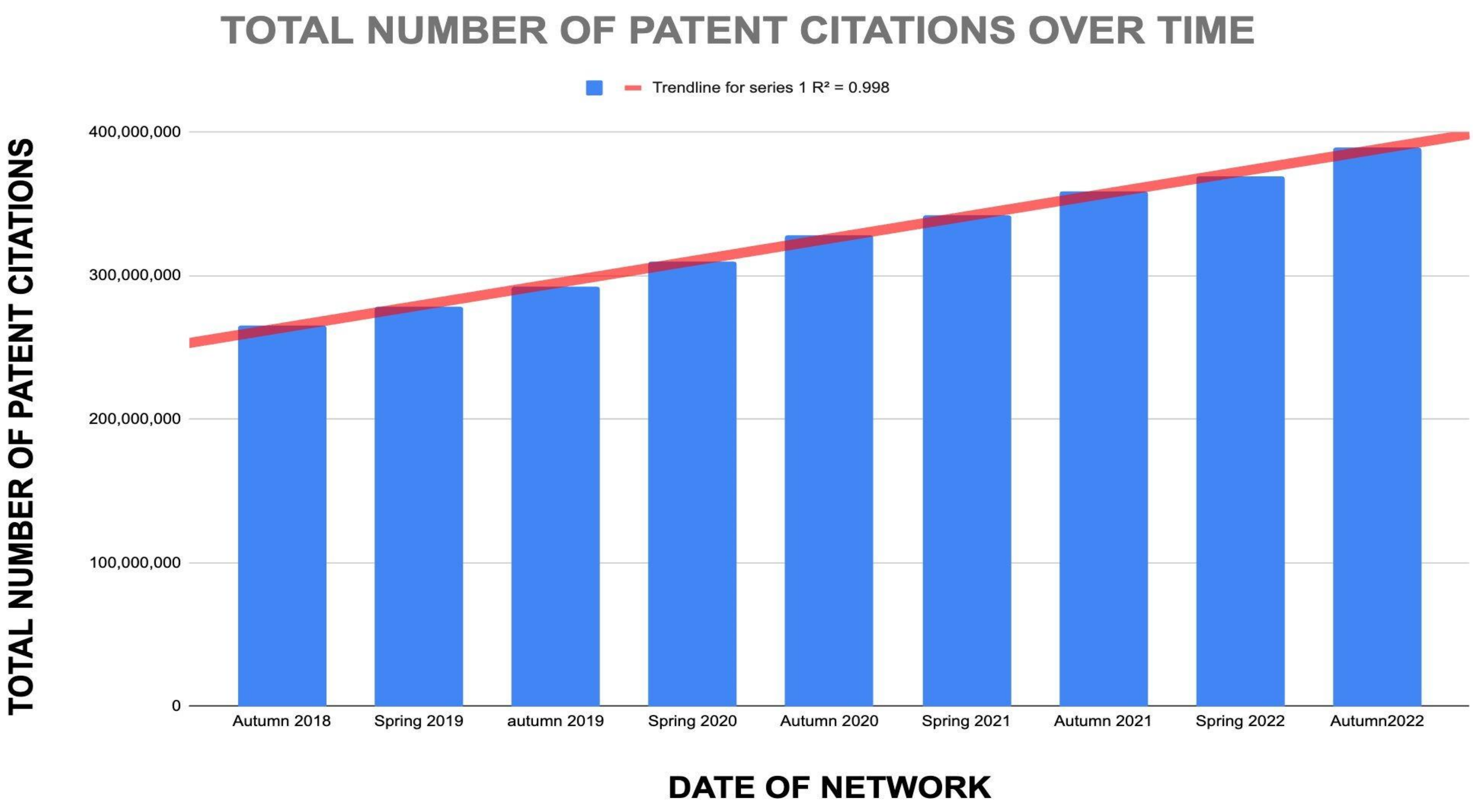
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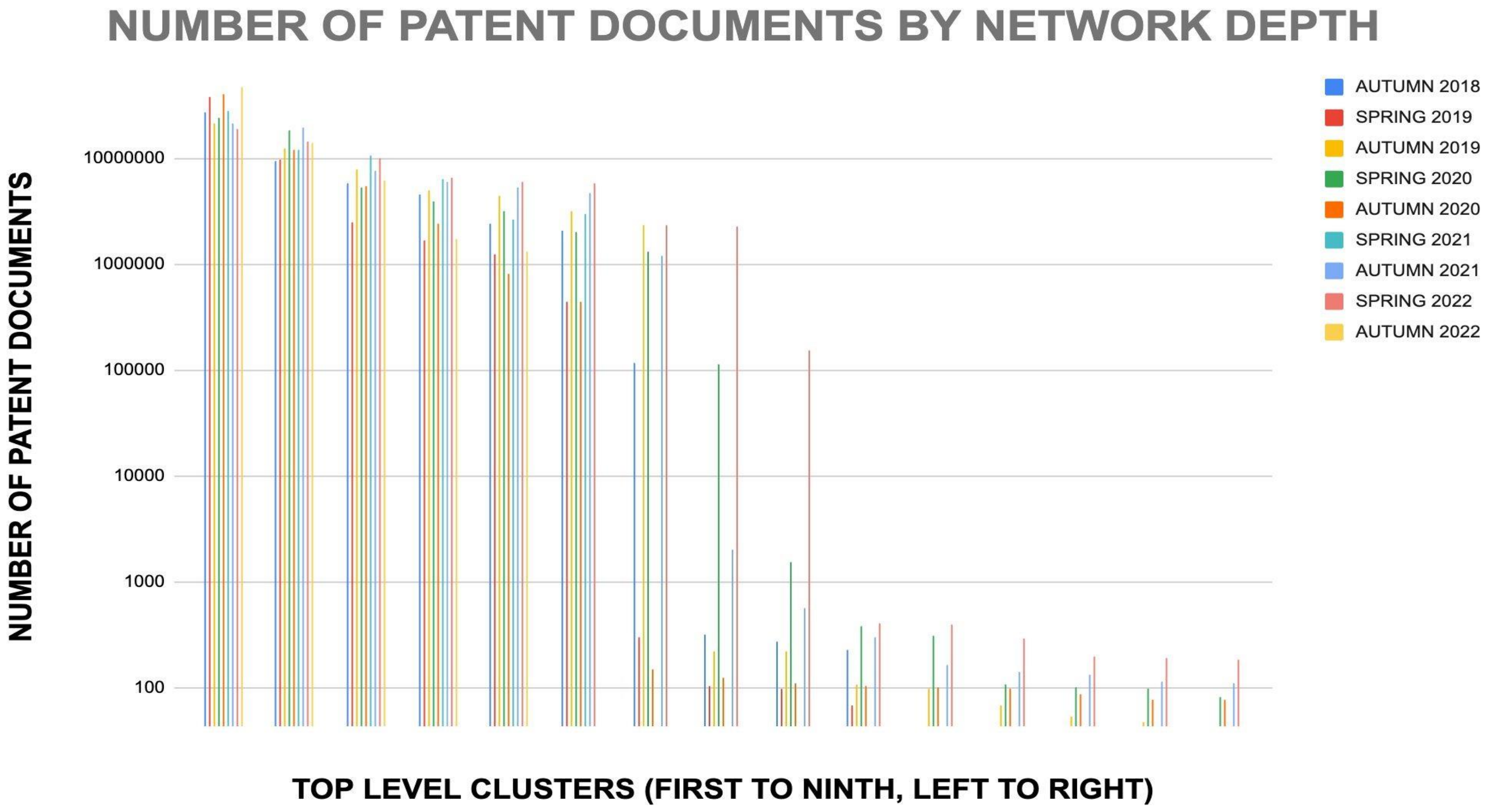

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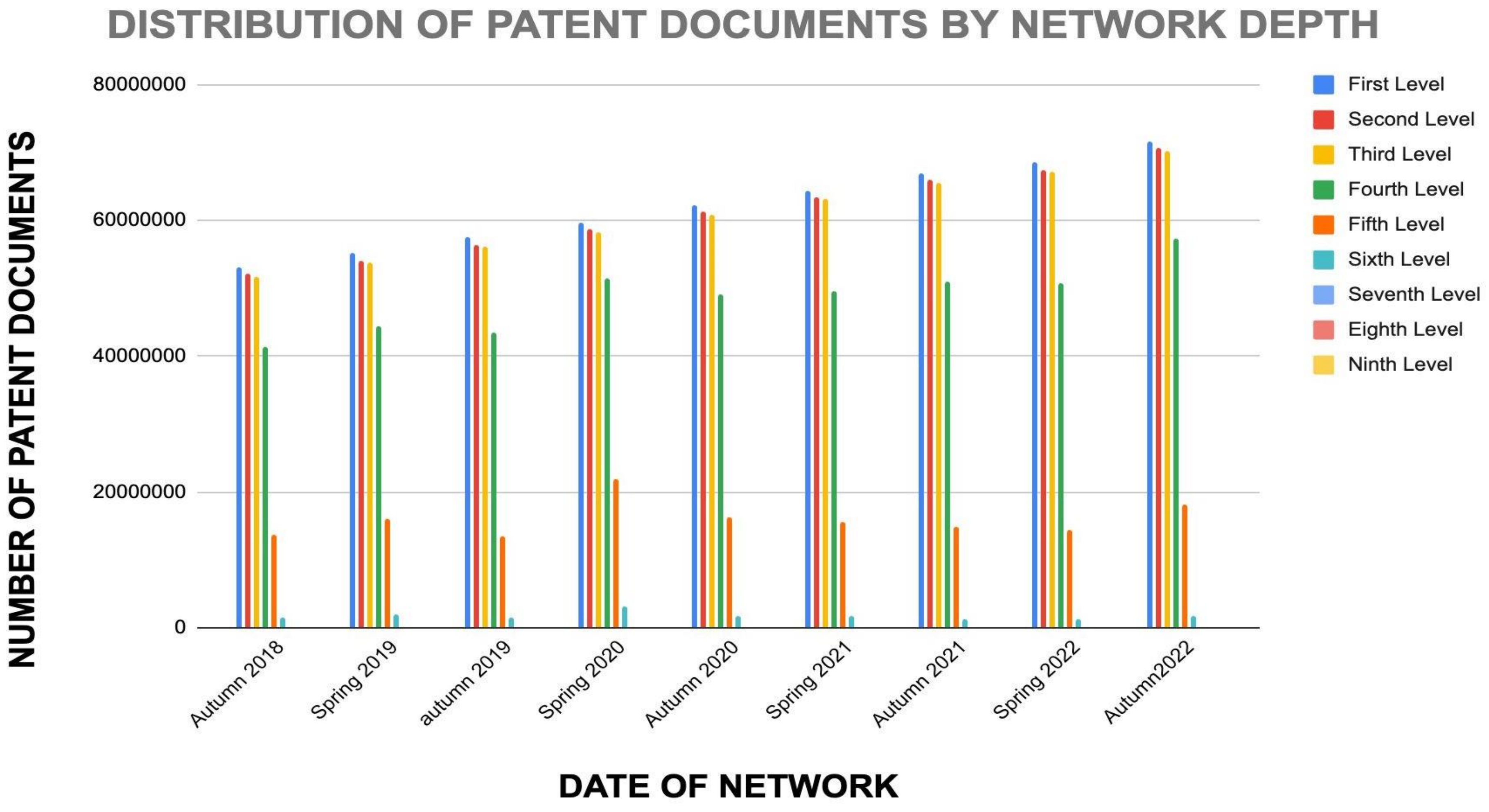
AUTUMN 2022



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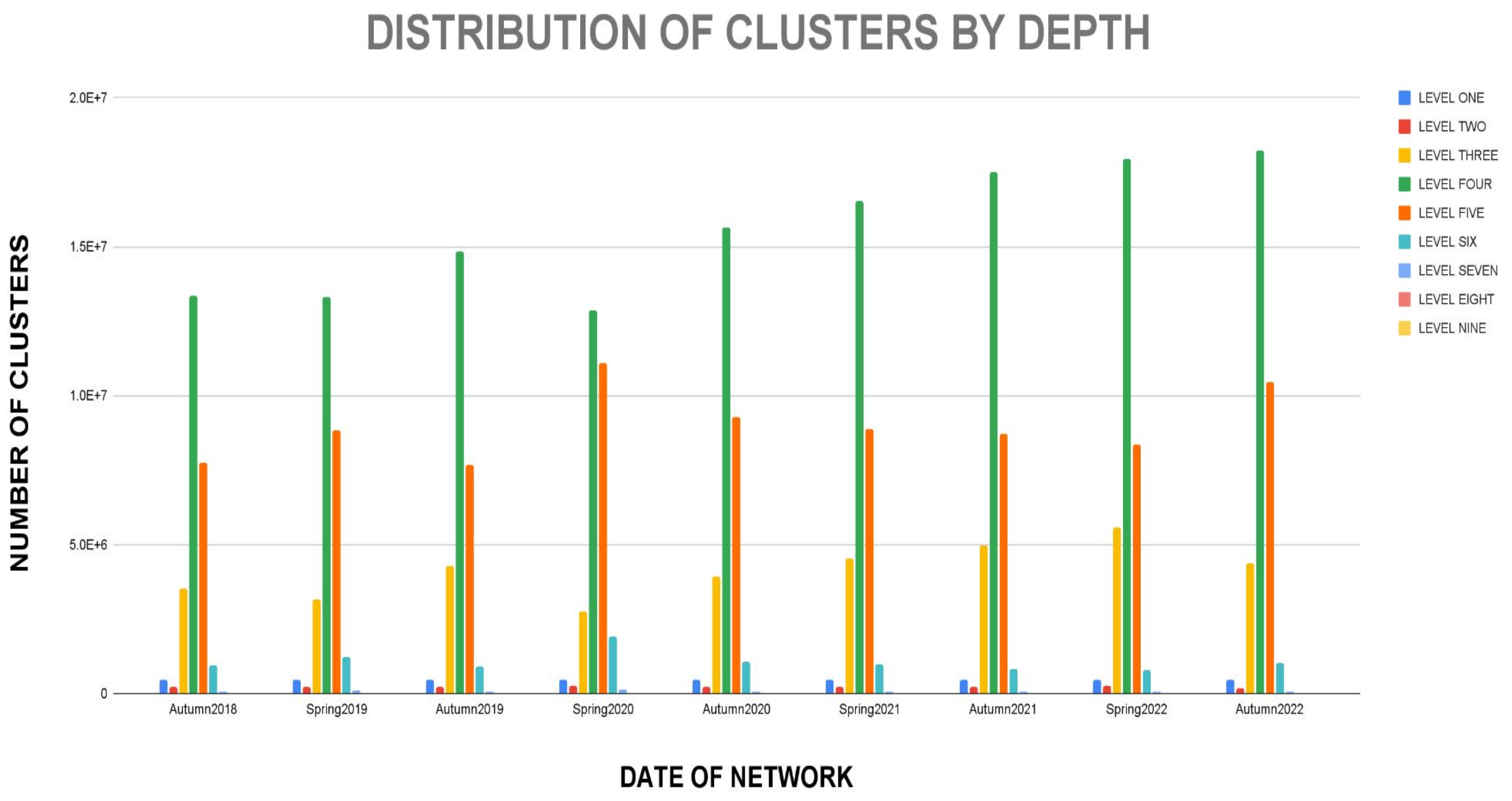
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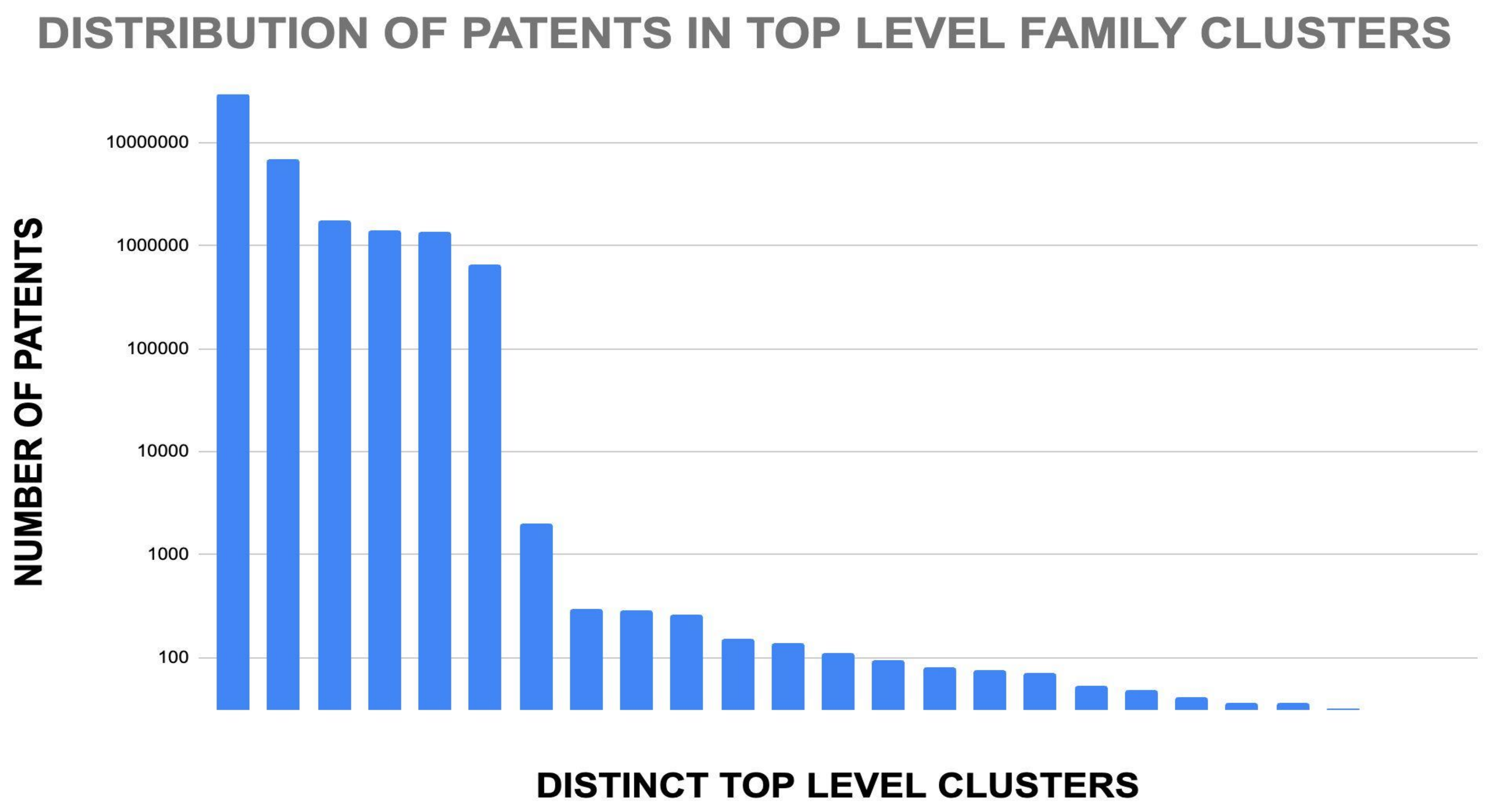
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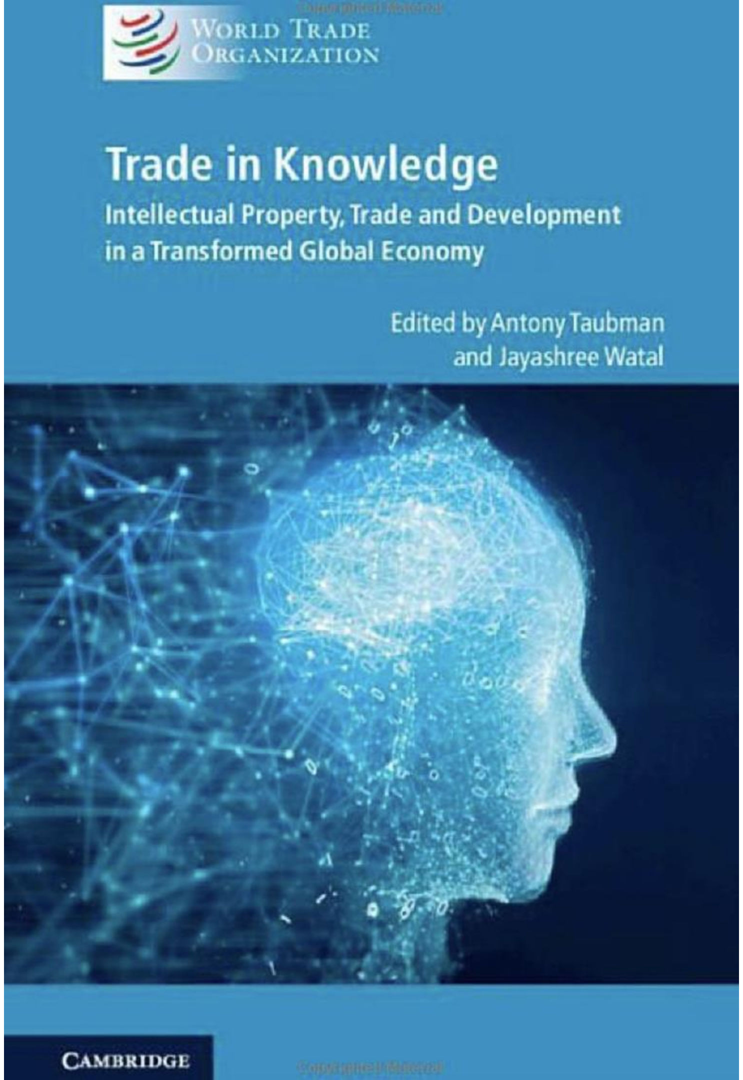


2022

7

Global Ebbs and Flows of Patent Knowledge

ANDREW W. TORRANCE, JEVIN D. WEST
AND LISA C. FRIEDMAN

Abstract

We use patent citation data to map the flows of technical knowledge, and in particular to test three hypotheses. First, that the net flow of technical knowledge tends to be from more developed to less developed countries. Second, that the trajectory of climate change-mitigation knowledge flow increased (especially from developed to developing countries) after the 1997 Kyoto Protocol and the 2015 Paris Agreement on climate change. Third, that the trajectory of pharmaceutical knowledge flow increased after the conclusion of the TRIPS Agreement. We find that massive amounts of technical information are exchanged, among countries around the world, in sometimes surprising patterns. Developed country patents supply a disproportionate amount of patent citations compared to patents from developing countries, and the importance of technical knowledge thereby transferred is disproportionately high. However, we observe some evidence that this imbalance in knowledge flow may be beginning to reverse itself, as developing country patents have become increasingly cited by those in developed countries, and the importance of developing world patents has grown. We did not discern evidence that the Kyoto Protocol has spurred knowledge flow in climate-mitigation technology, but found some preliminary evidence consistent with an effect by the Paris Agreement. We did find evidence consistent with the possibility that the TRIPS Agreement may have spurred pharmaceutical (and more general) knowledge flow.

Introduction

Patents and patent applications contain rich sources of scientific and technical information. By their very name, patents – derived from a Latin word meaning 'open' – make their information freely available to the public. They describe new devices, machines, systems, molecules and even living organisms, as well as methods for making and using them. Transfer of technical knowledge among people, firms, institutions and governments

https://doi.org/10.1017/9781108780919.010 Published online by Cambridge University Press

FIGURE 23. RADIAL DIAGRAM OF INTERNATIONAL KNOWLEDGE FLOW

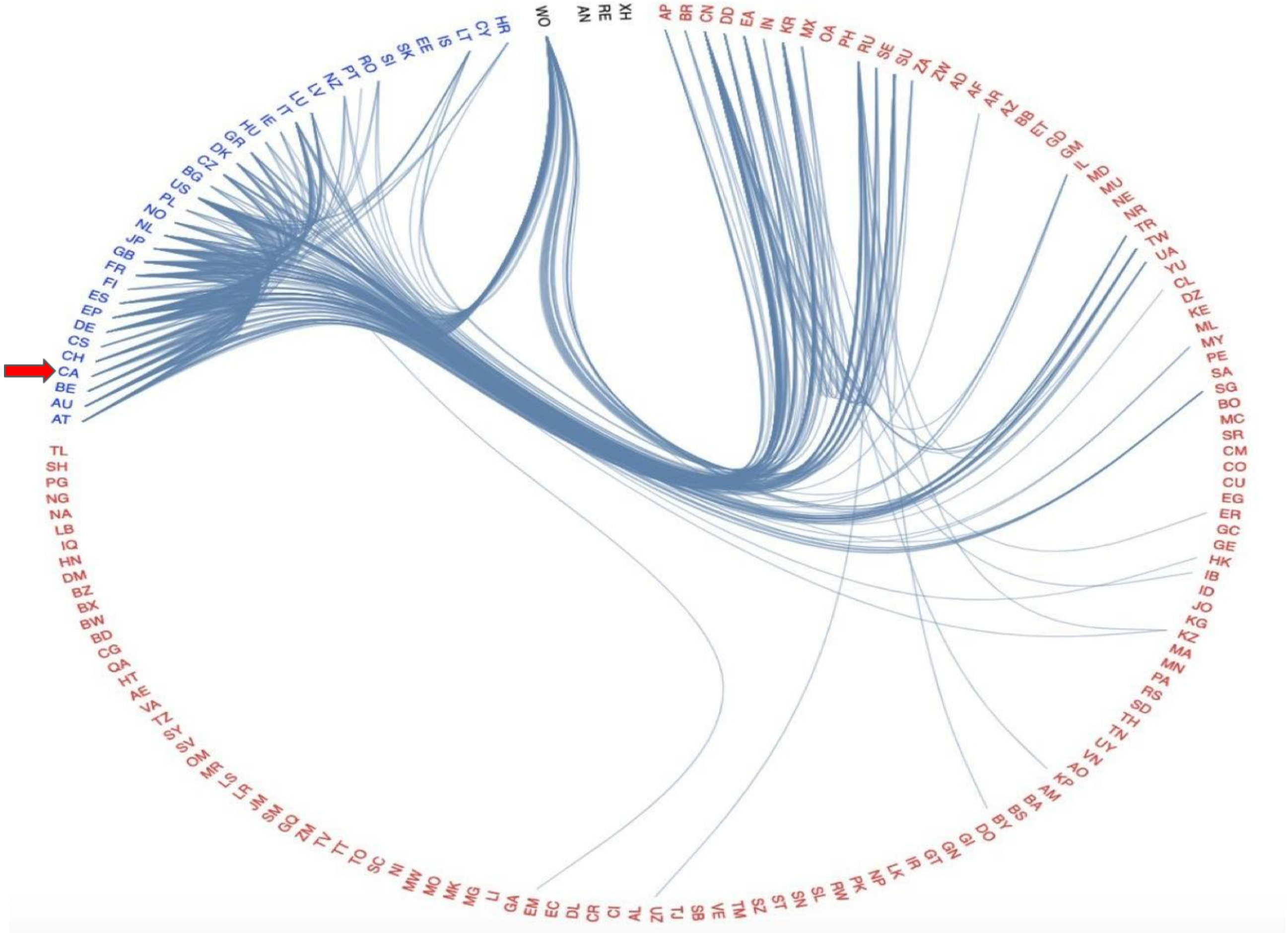
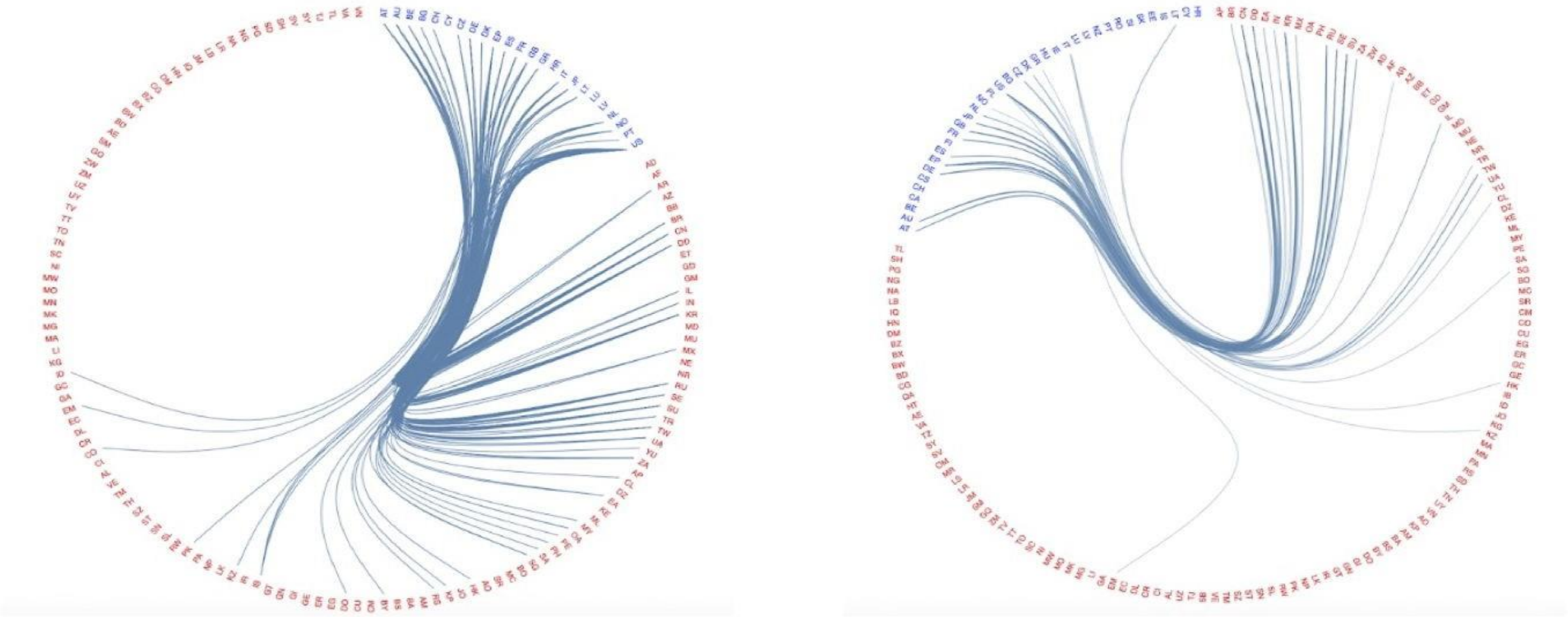
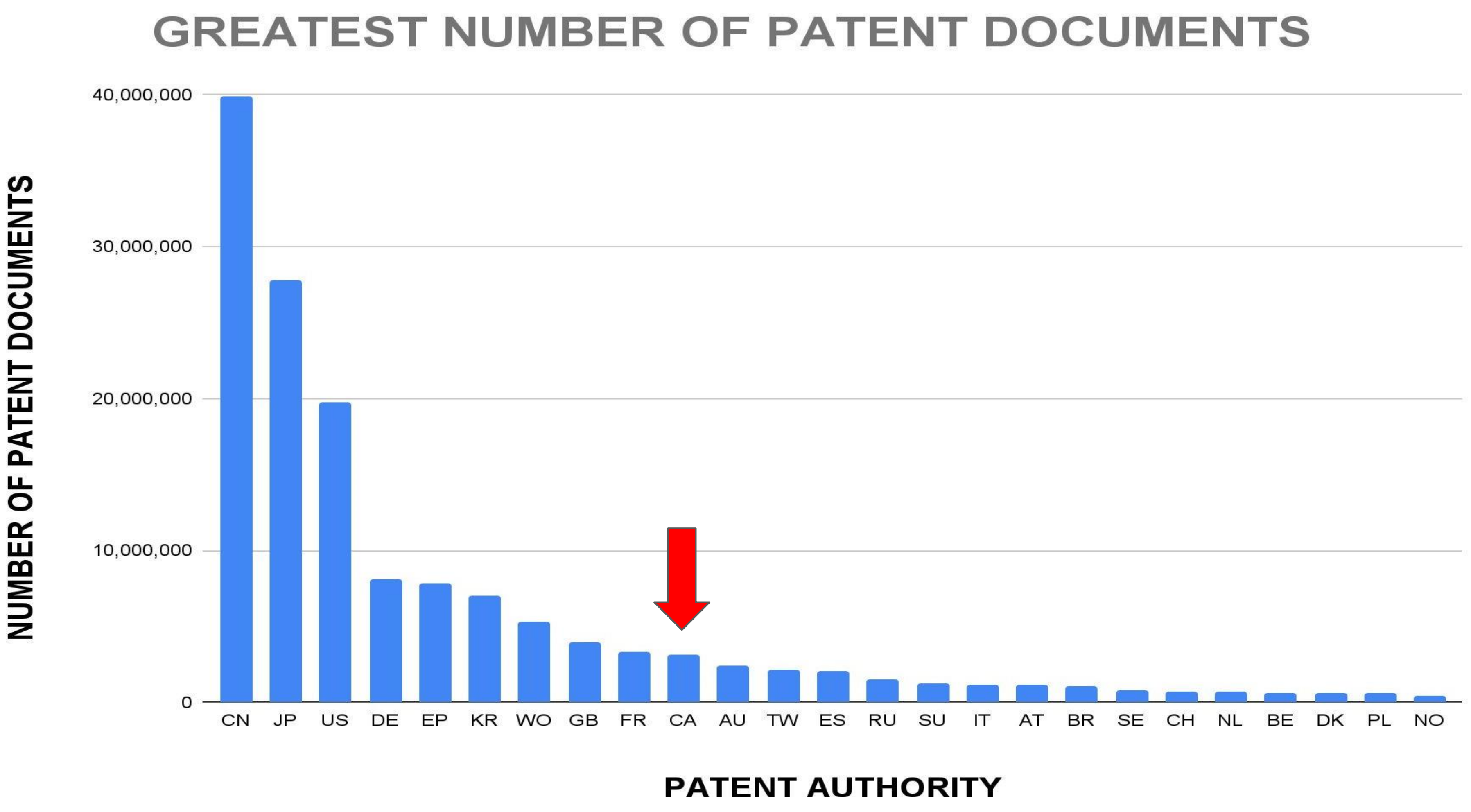


FIGURE 24. DIRECTIONAL KNOWLEDGE FLOW BETWEEN DEVELOPED AND DEVELOPING WORLD COUNTRIES



Developed → Developing

Developing → Developed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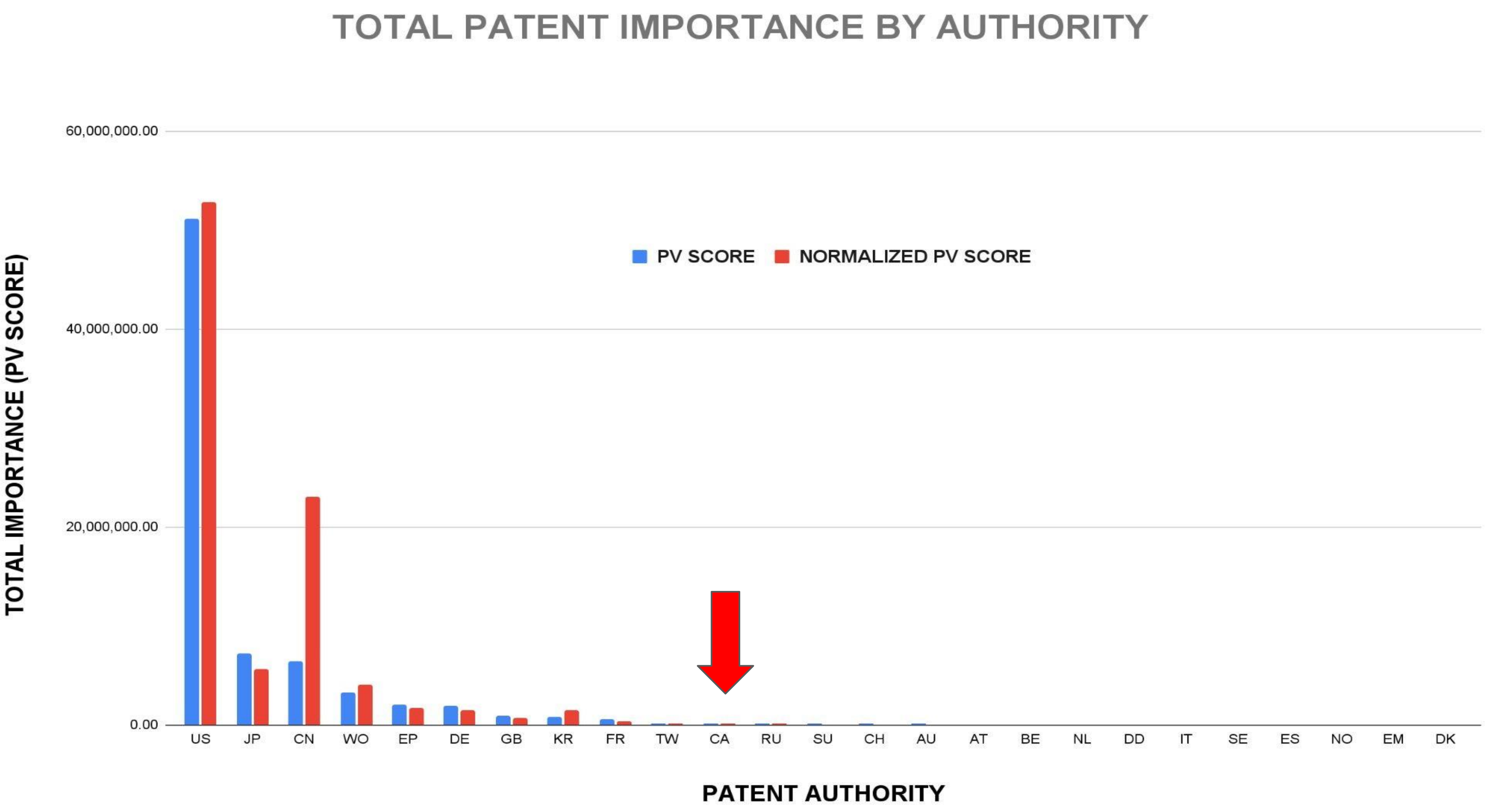
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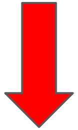

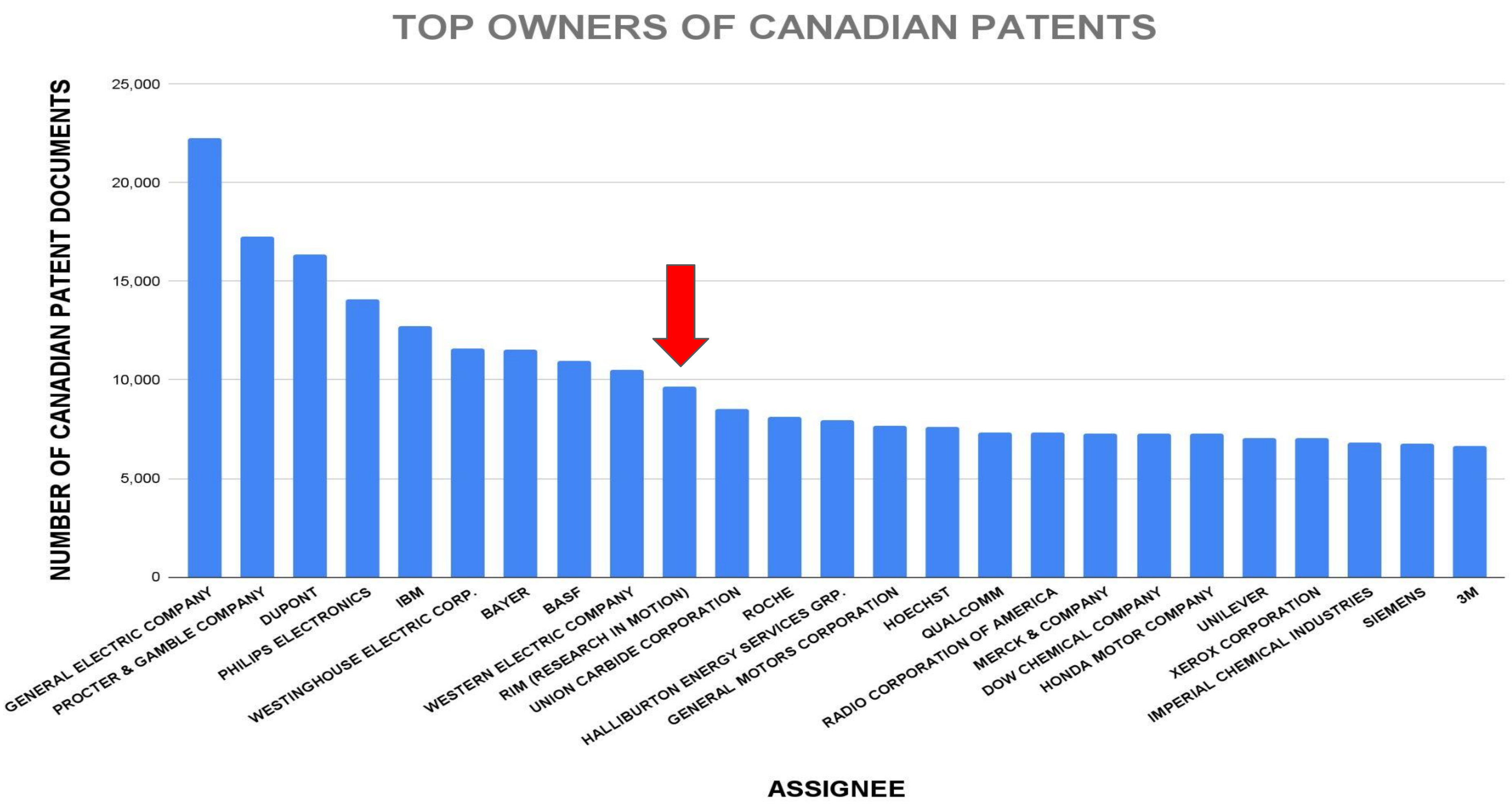

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PROCTER & GAMBLE COMPANY
DUPONT
PHILIPS ELECTRONICS
IBM
WESTINGHOUSE ELECTRIC CORP.
BAYER
BASF
WESTERN ELECTRIC COMPANY
RIM (RESEARCH IN MOTION)
UNION CARBIDE CORPORATION
ROCHE
HALLIBURTON ENERGY SERVICES GRP.
GENERAL MOTORS CORPORATION
HOECHST
QUALCOMM
RADIO CORPORATION OF AMERICA
MERCK & COMPANY
DOW CHEMICAL COMPANY
HONDA MOTOR COMPANY
UNILEVER
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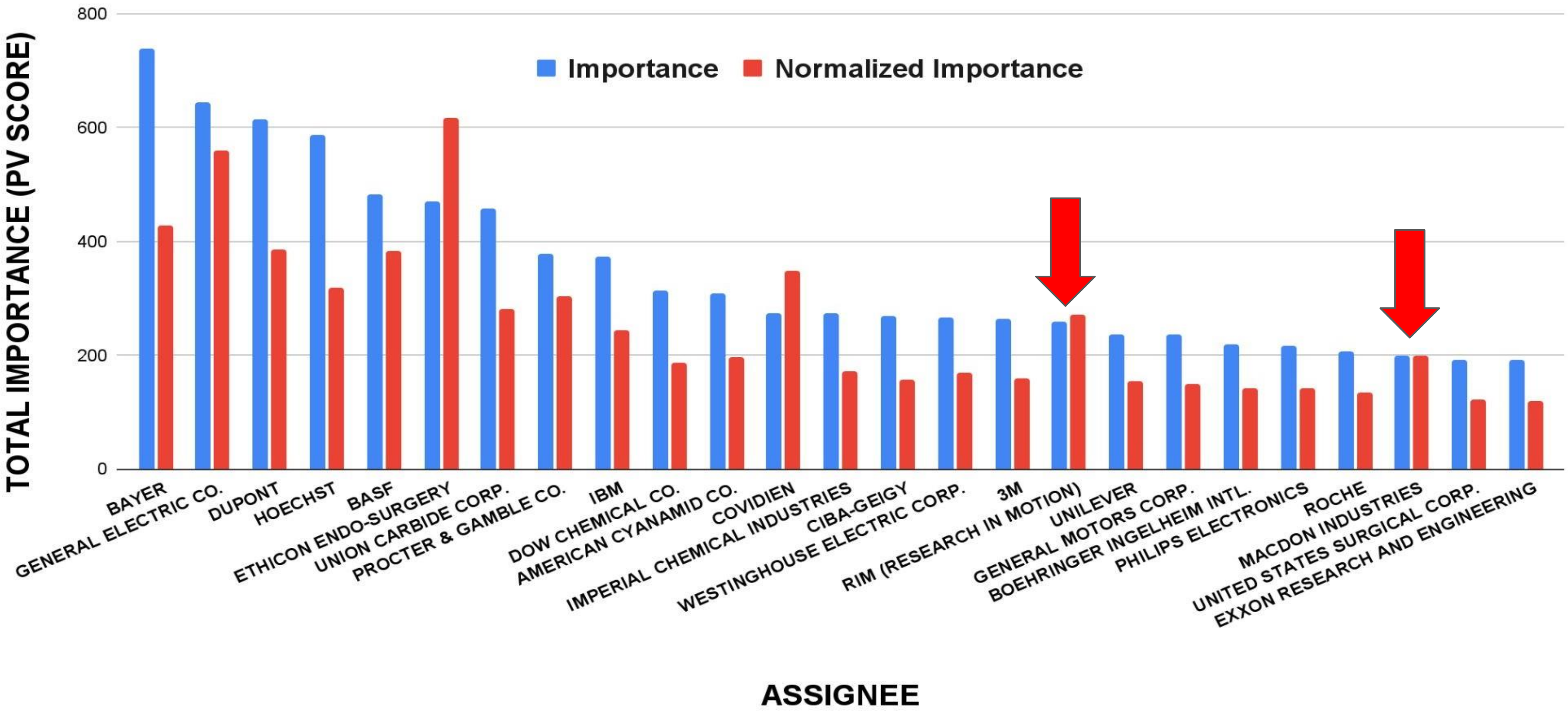
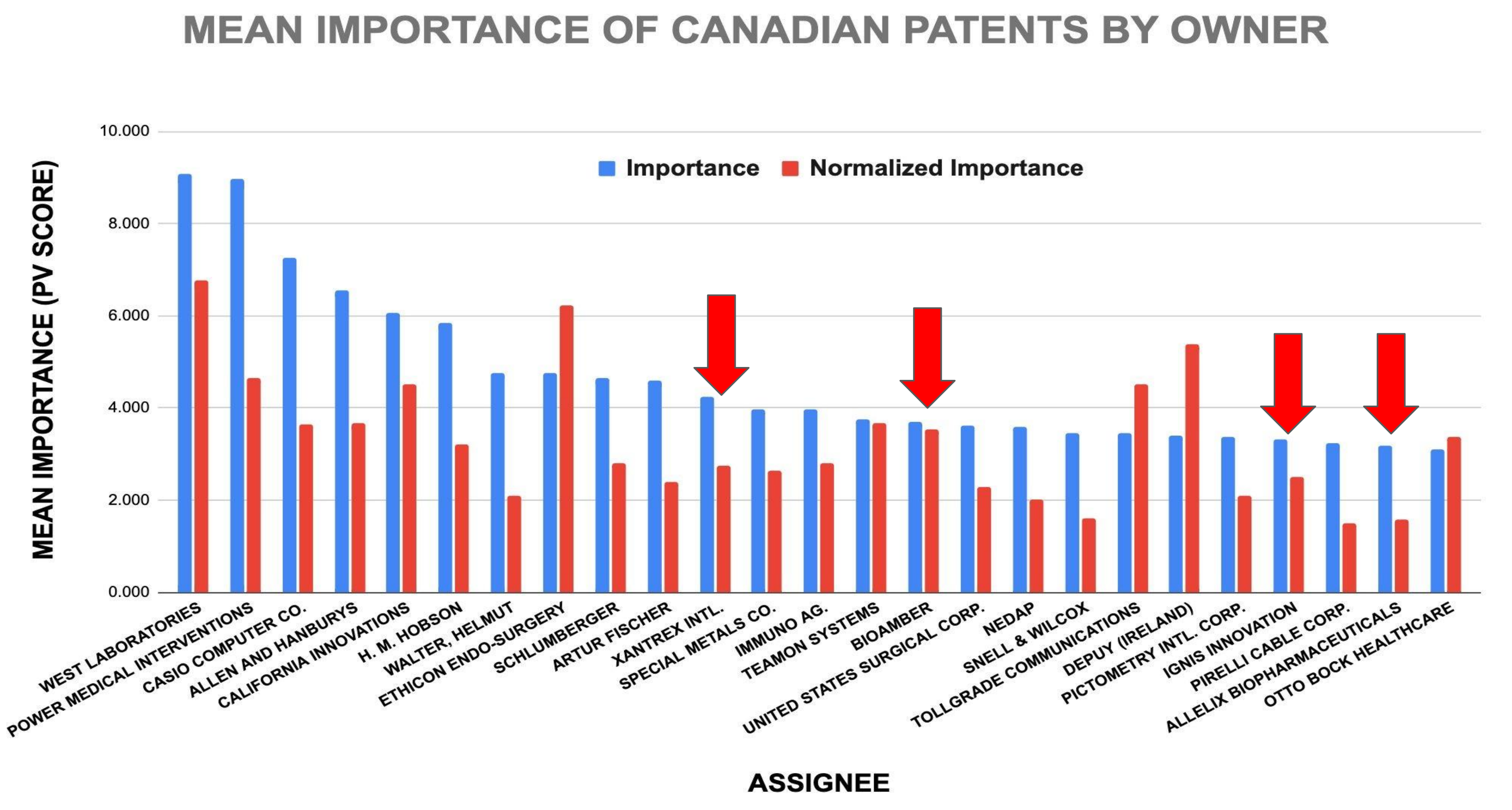
3M
ASSIGNEE

TOTAL IMPORTANCE OF CANADIAN PATENTS BY OWNER




MEAN IMPORTANCE OF CANADIAN PATENTS BY OWNER
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Normalized Importance
MEAN IMPORTANCE (PV SCORE)
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0.000
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ALLEN AND HANBURYS
CALIFORNIA INNOVATIONS
H. M. HOBSON
WALTER, HELMUT
ETHICON ENDO-SURGERY
SCHLUMBERGER
ARTUR FISCHER
XANTREX INTL.
SPECIAL METALS CO.
IMMUNO AG.
TEAMON SYSTEMS
BIOAMBER
UNITED STATES SURGICAL CORP.
NEDAP
SNELL & WILCOX
TOLLGRADE COMMUNICATIONS
DEPUY (IRELAND)
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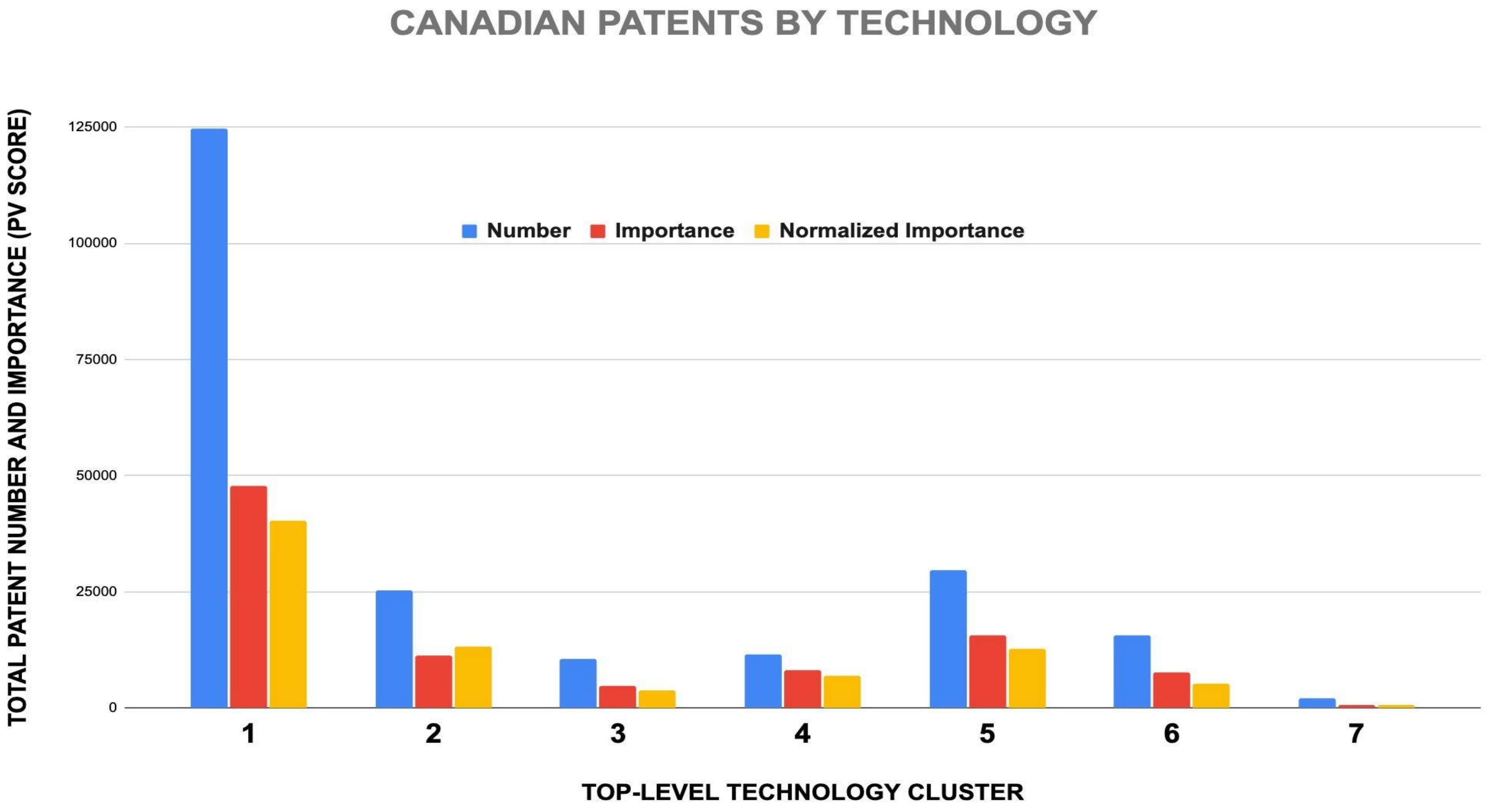
ALLELIX BIOPHARMACEUTICALS
OTTO BOCK HEALTHCARE
ASSIGNEE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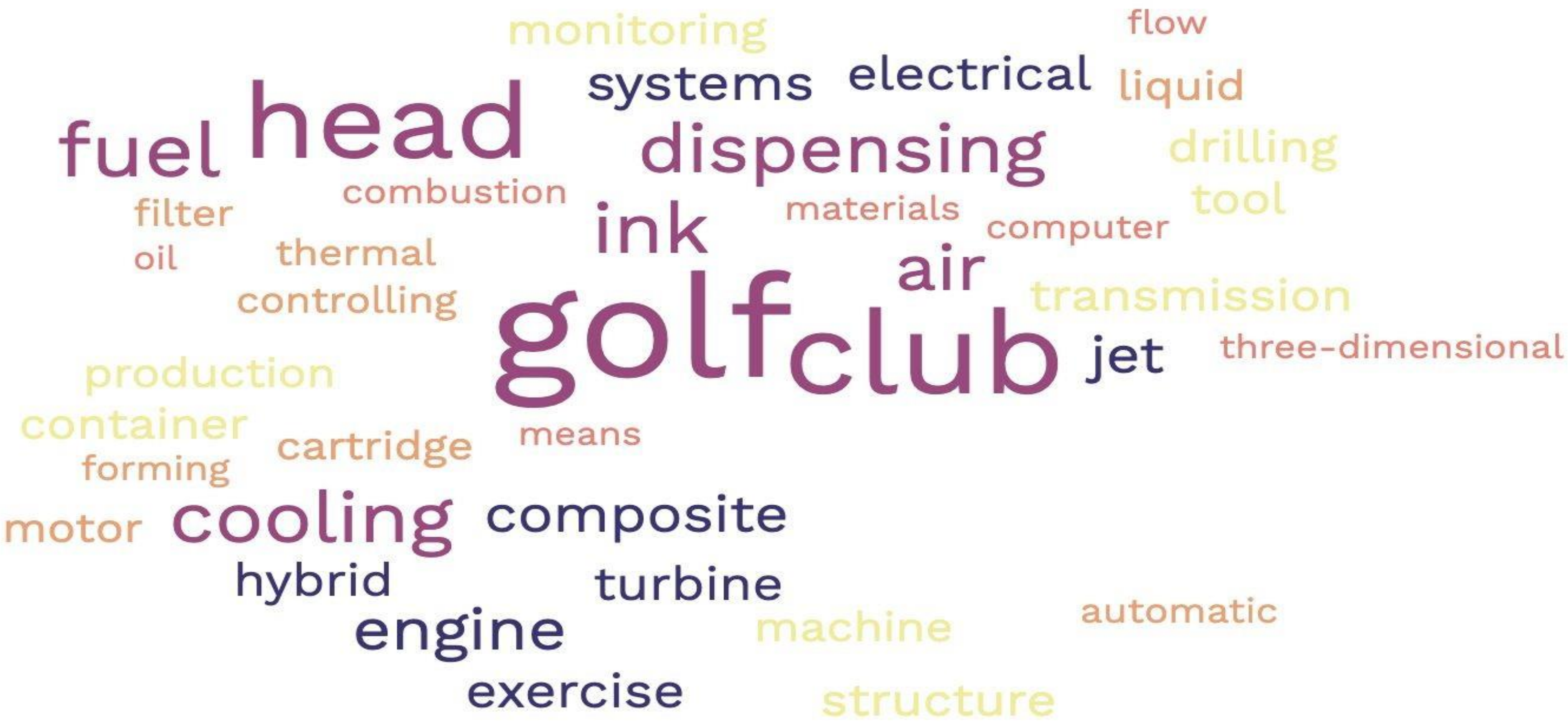
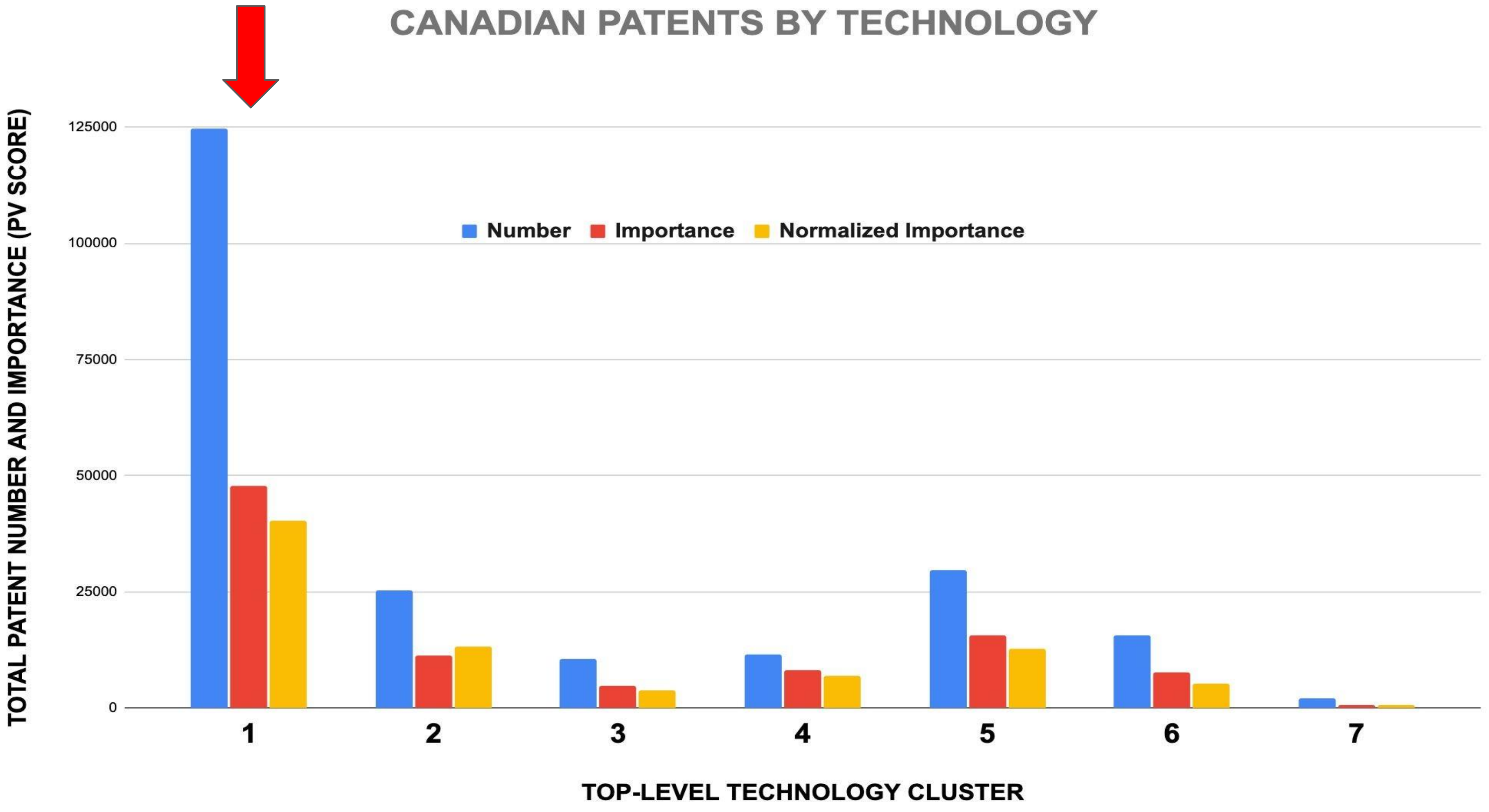
TOP-LEVEL TECHNOLOGY CLUSTER

TOP-LEVEL CLUSTER 1

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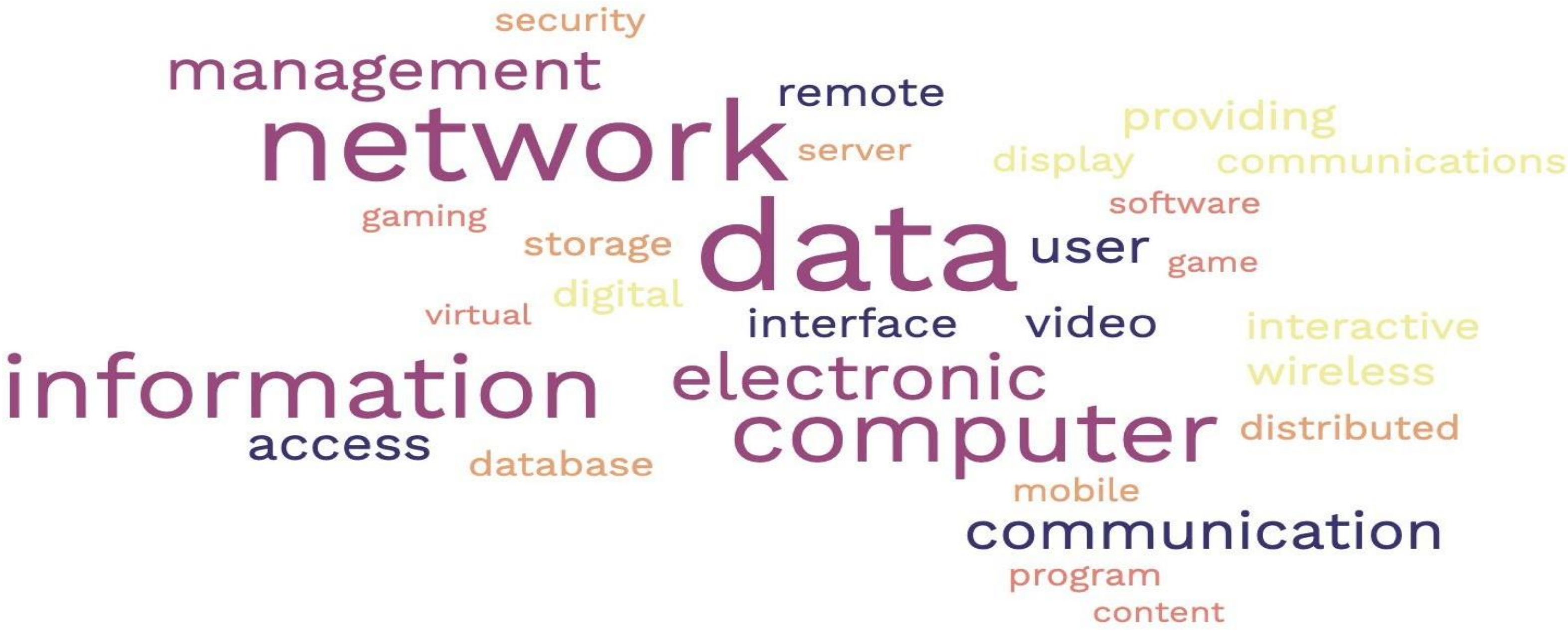
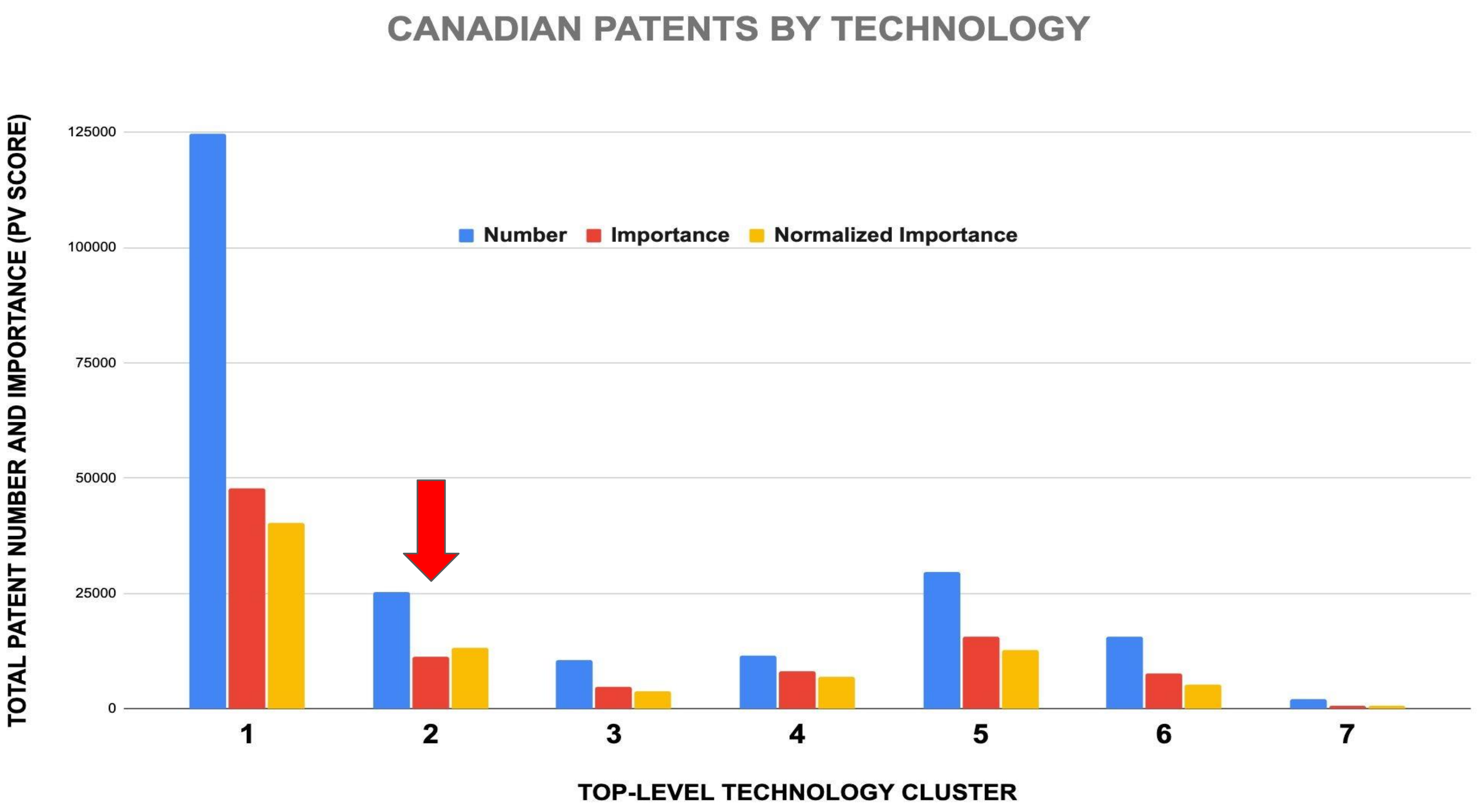
TOP-LEVEL TECHNOLOGY CLUSTER

TOP-LEVEL CLUSTER 2

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TOTAL PATENT NUMBER AND IMPORTANCE (PV SCORE)
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Normalized Importance
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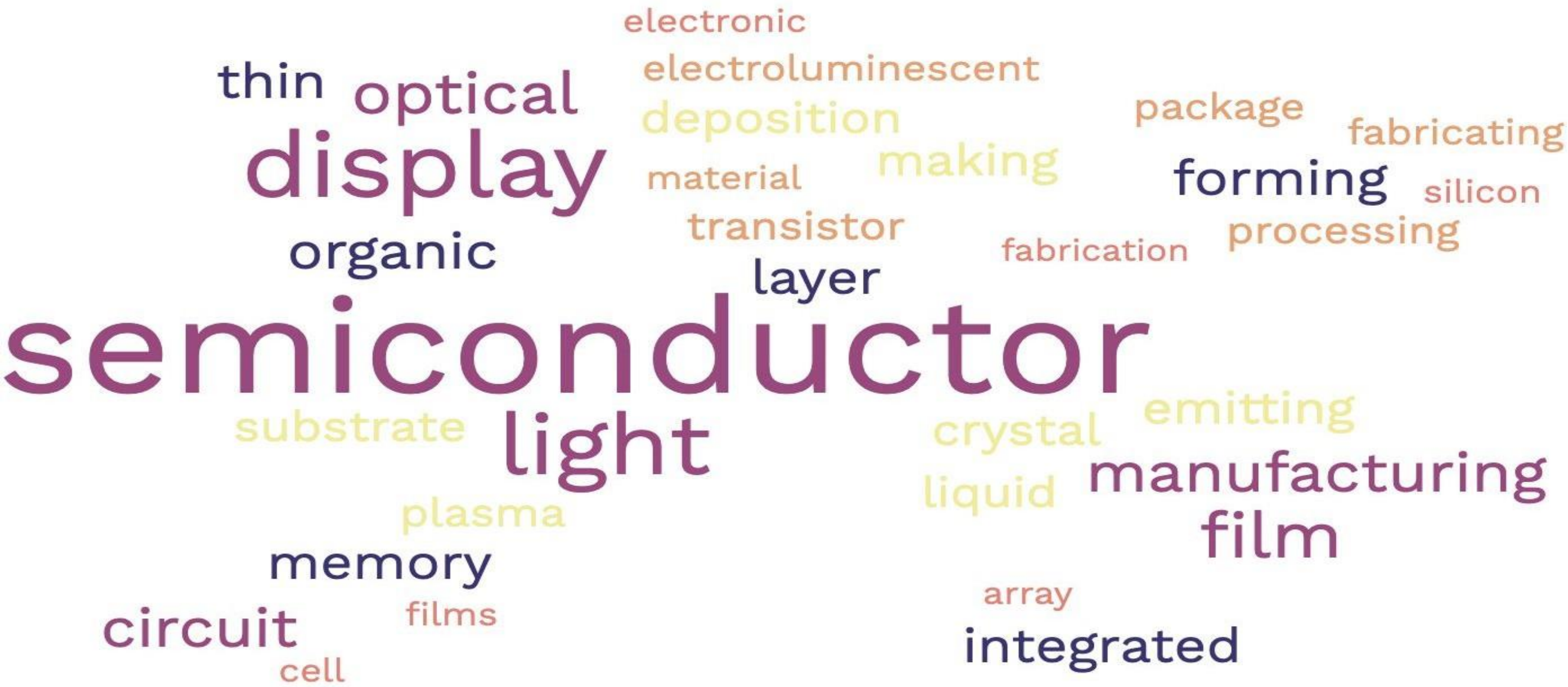
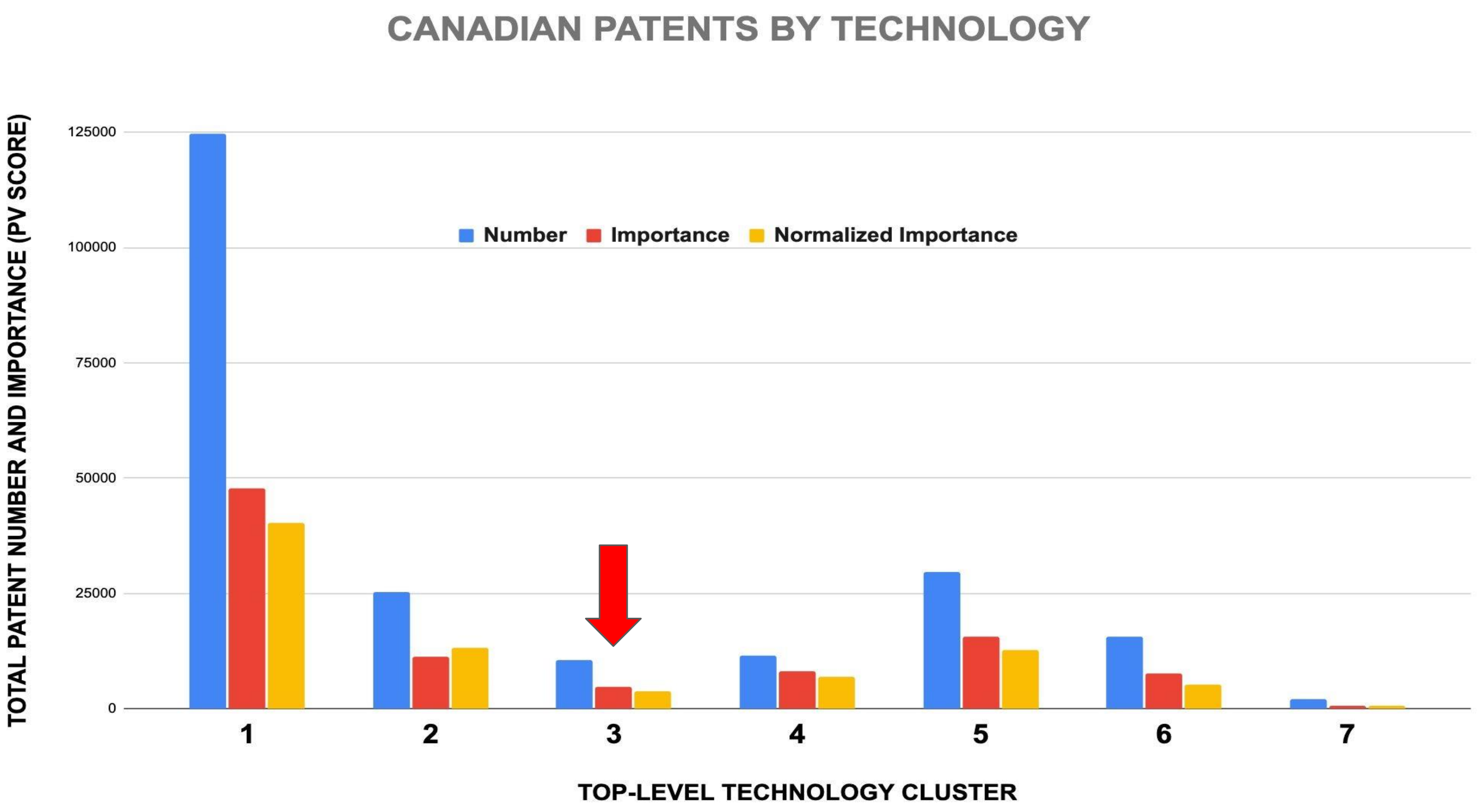
TOP-LEVEL TECHNOLOGY CLUSTER

TOP-LEVEL CLUSTER 3

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Normalized Importance
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TOP-LEVEL TECHNOLOGY CLUSTER

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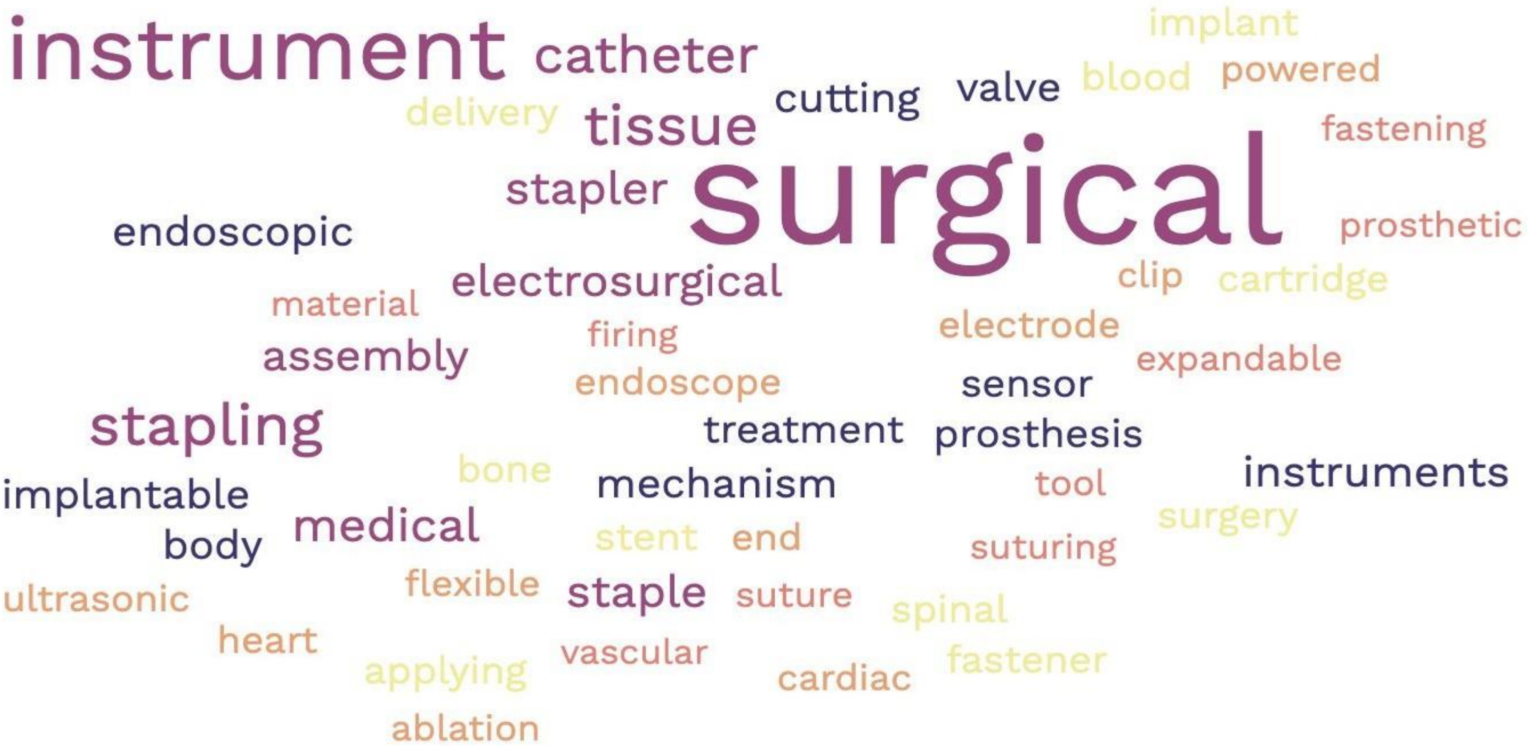

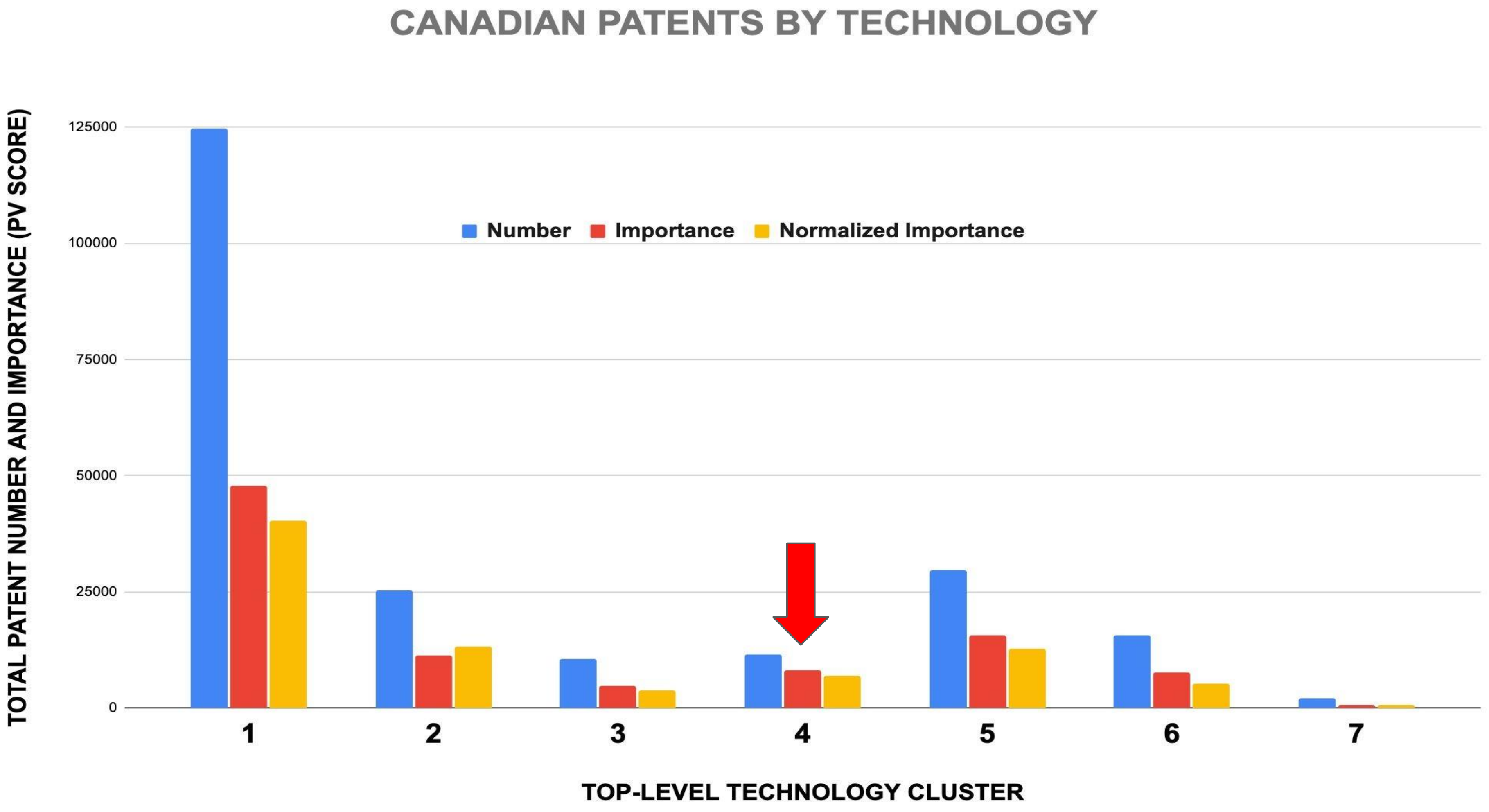
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Importance
Normalized Importance
TOTAL PATENT NUMBER AND IMPORTANCE (PV SCORE)
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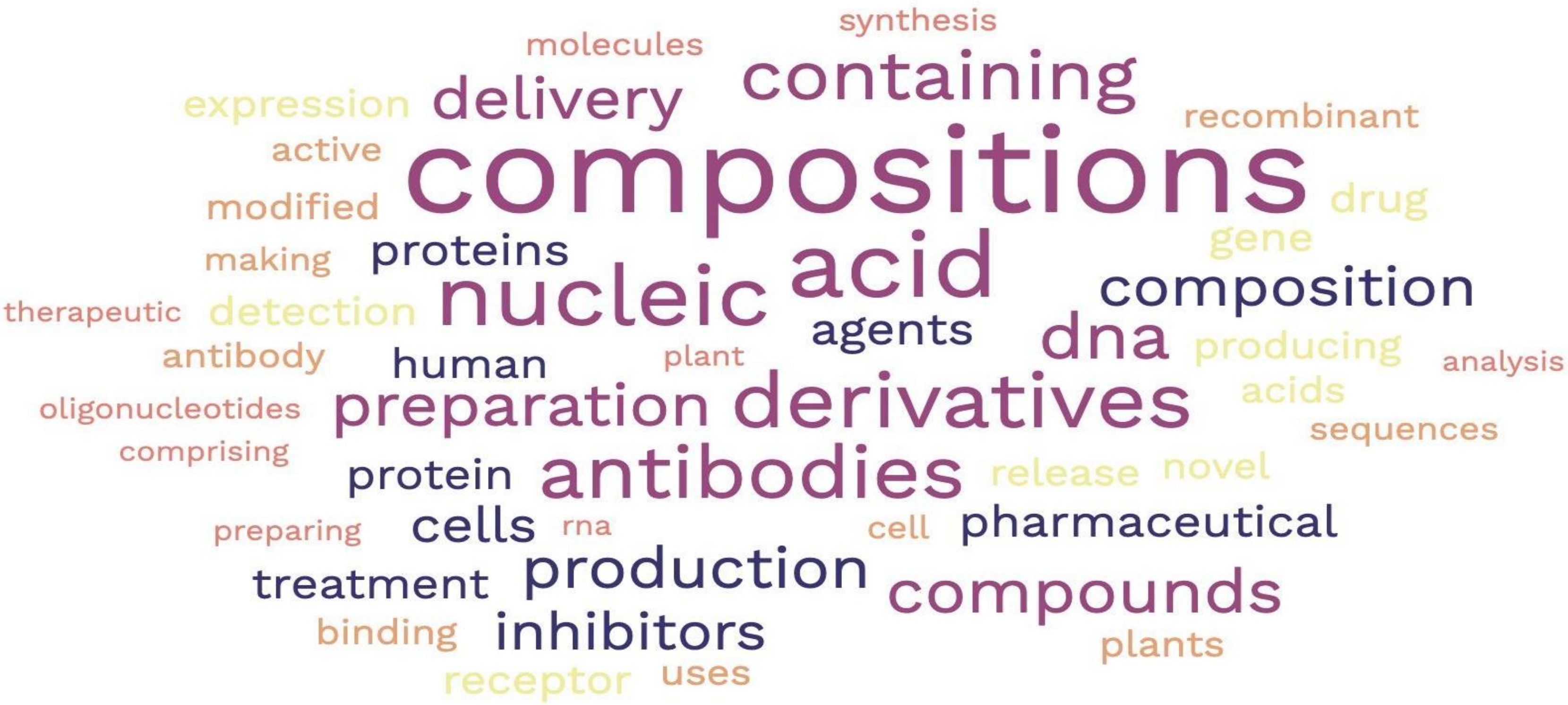
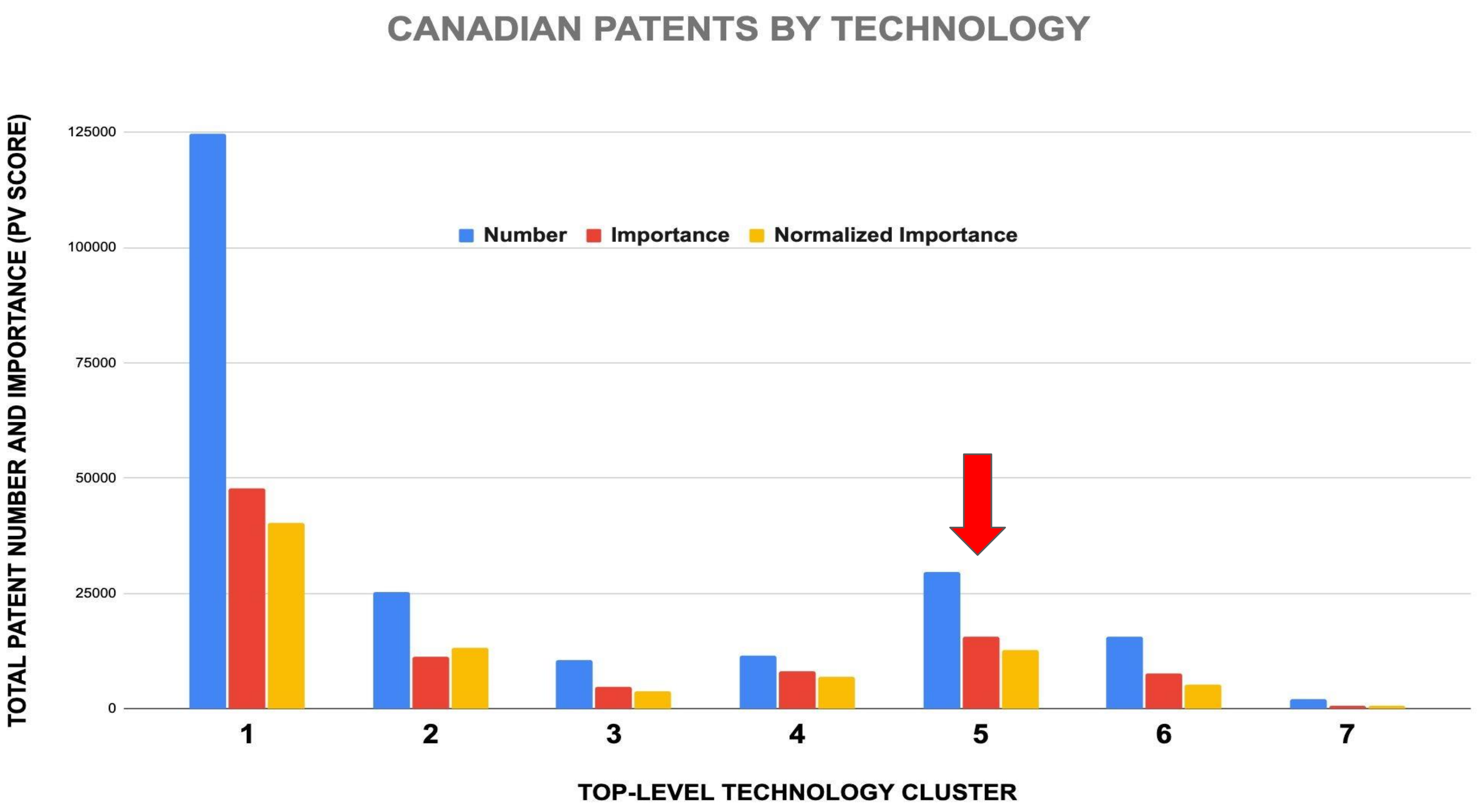
TOP-LEVEL TECHNOLOGY CLUSTER

TOP-LEVEL CLUSTER 5




CANADIAN PATENTS BY TECHNOLOGY
Number
Importance
Normalized Importance
TOTAL PATENT NUMBER AND IMPORTANCE (PV SCORE)
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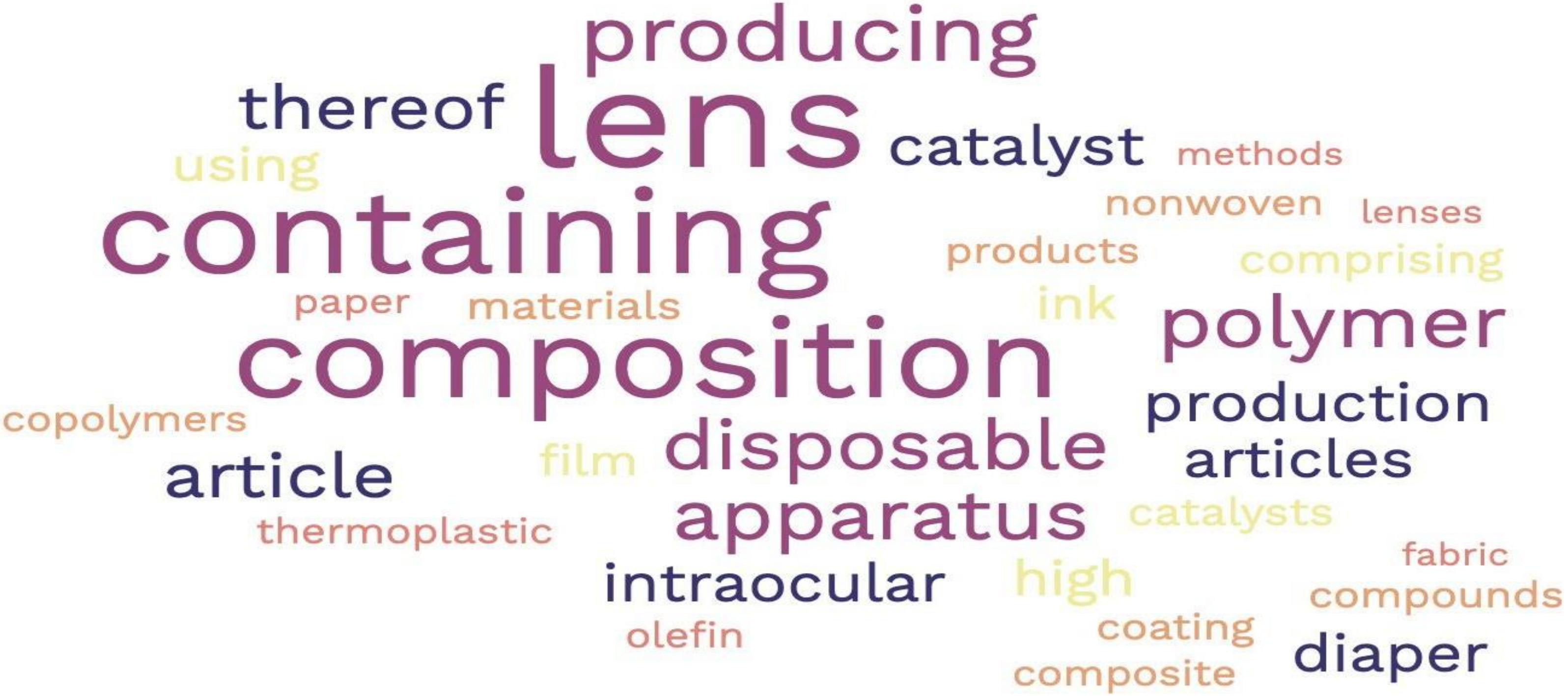
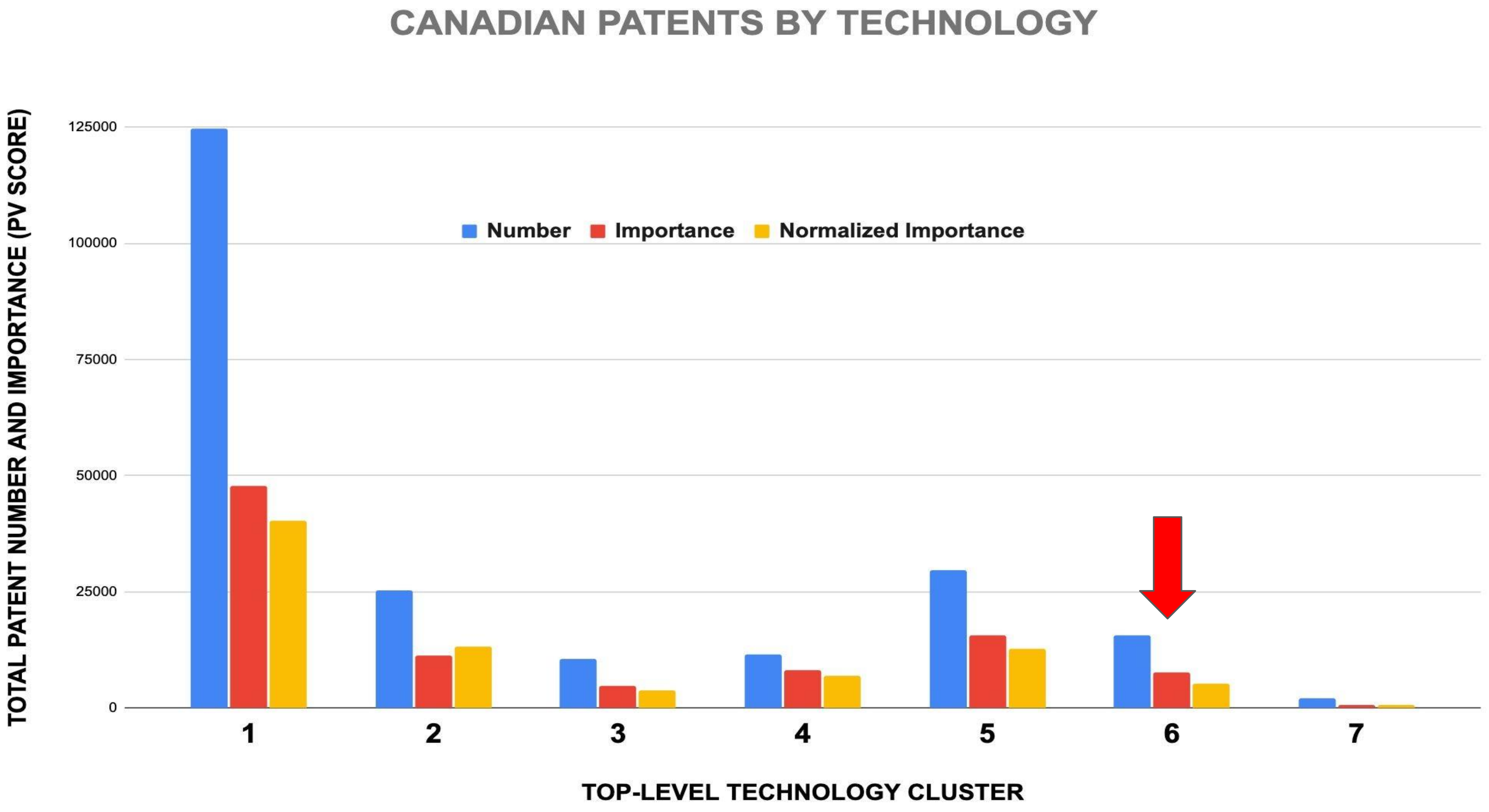
TOP-LEVEL TECHNOLOGY CLUSTER

TOP-LEVEL CLUSTER 6




CANADIAN PATENTS BY TECHNOLOGY
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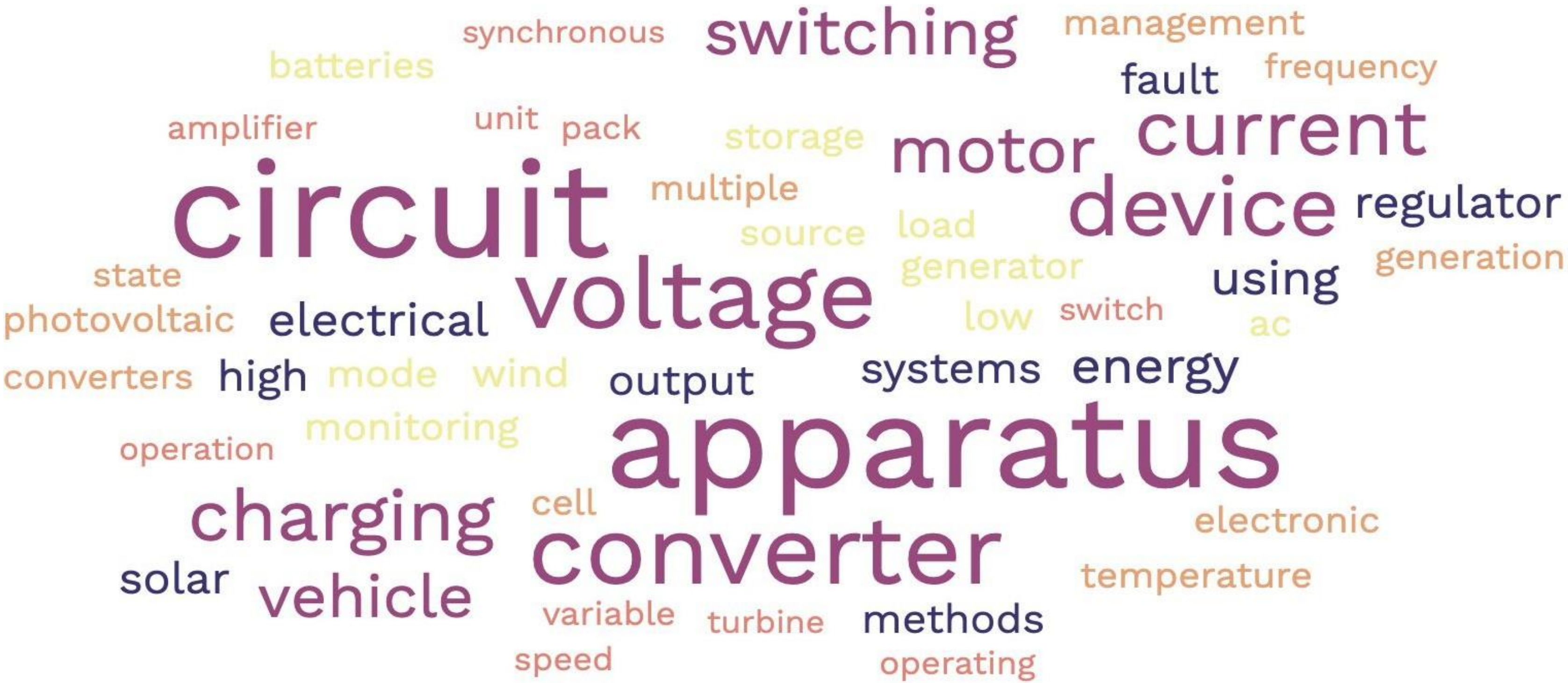
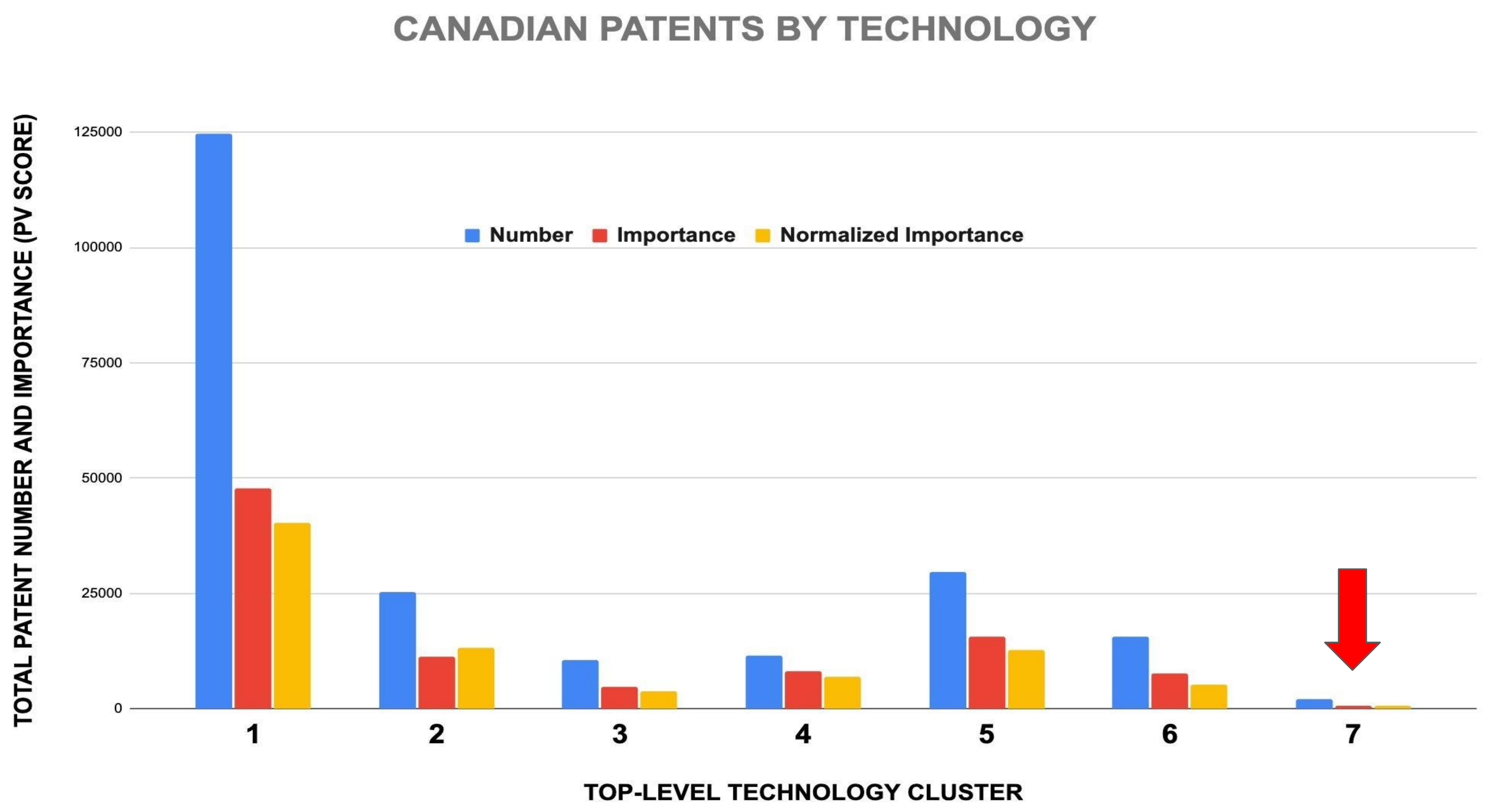
TOP-LEVEL CLUSTER 7

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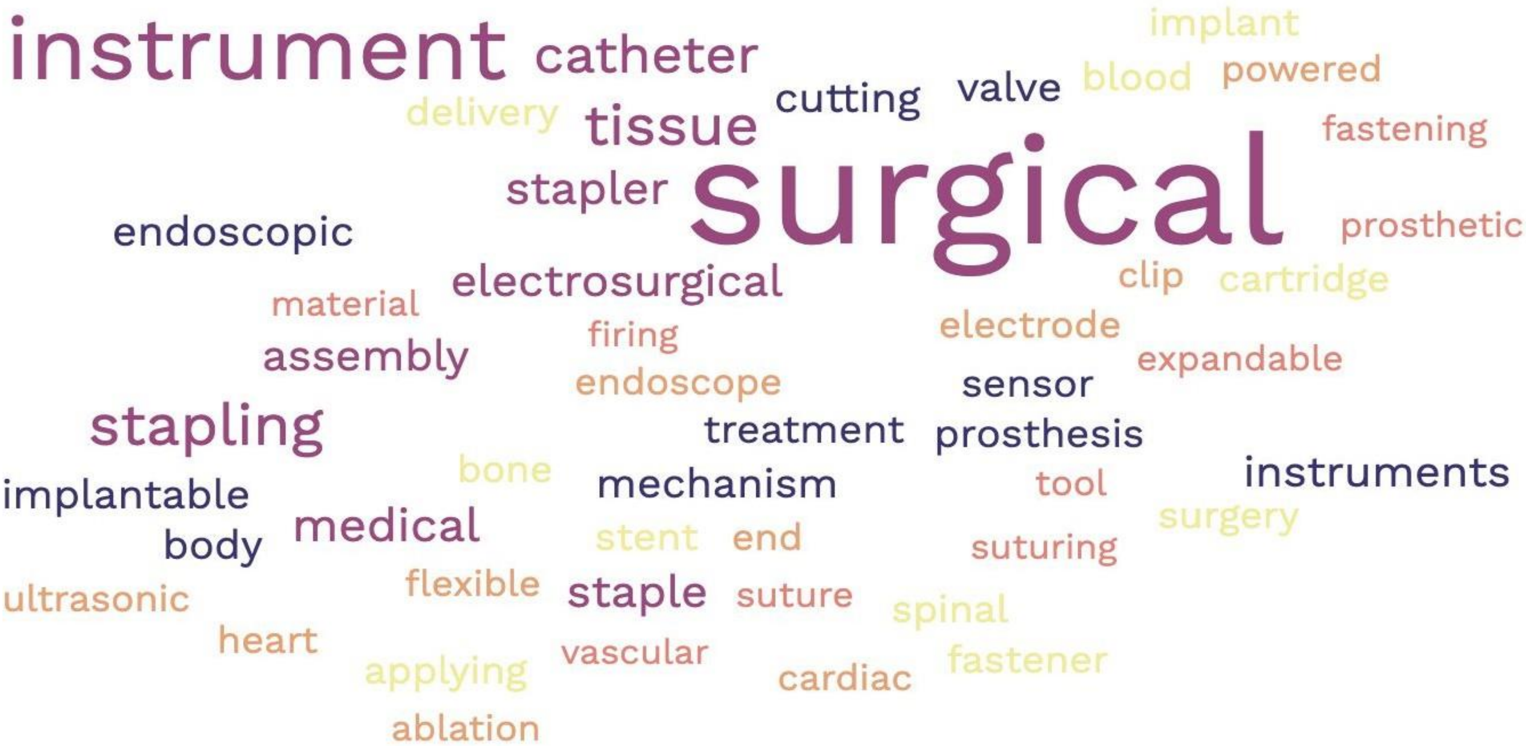
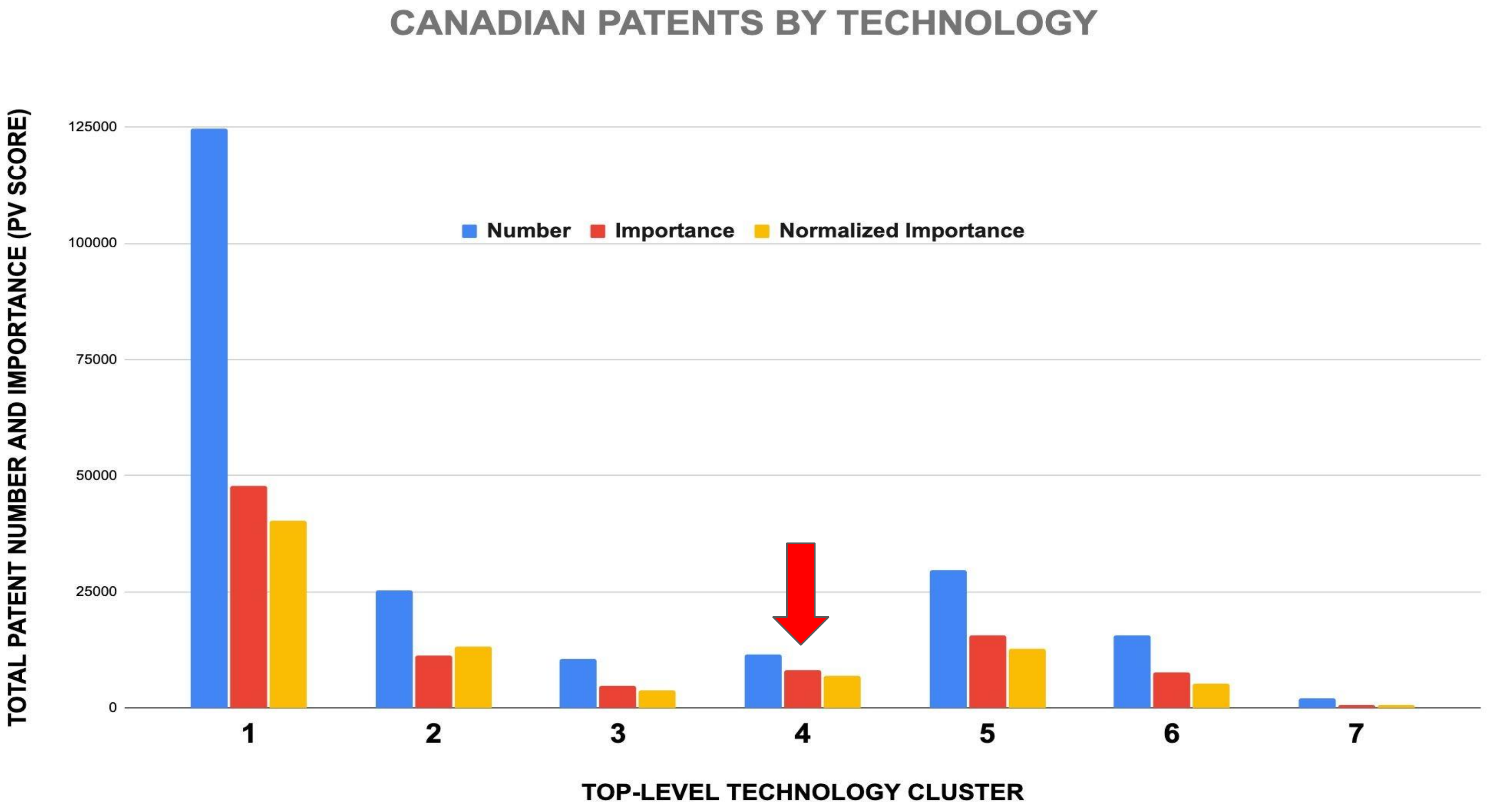
TOP-LEVEL TECHNOLOGY CLUSTER

CANADIAN EXCELLENCE





CANADIAN PATENTS BY TECHNOLOGY
Number
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Normalized Importance
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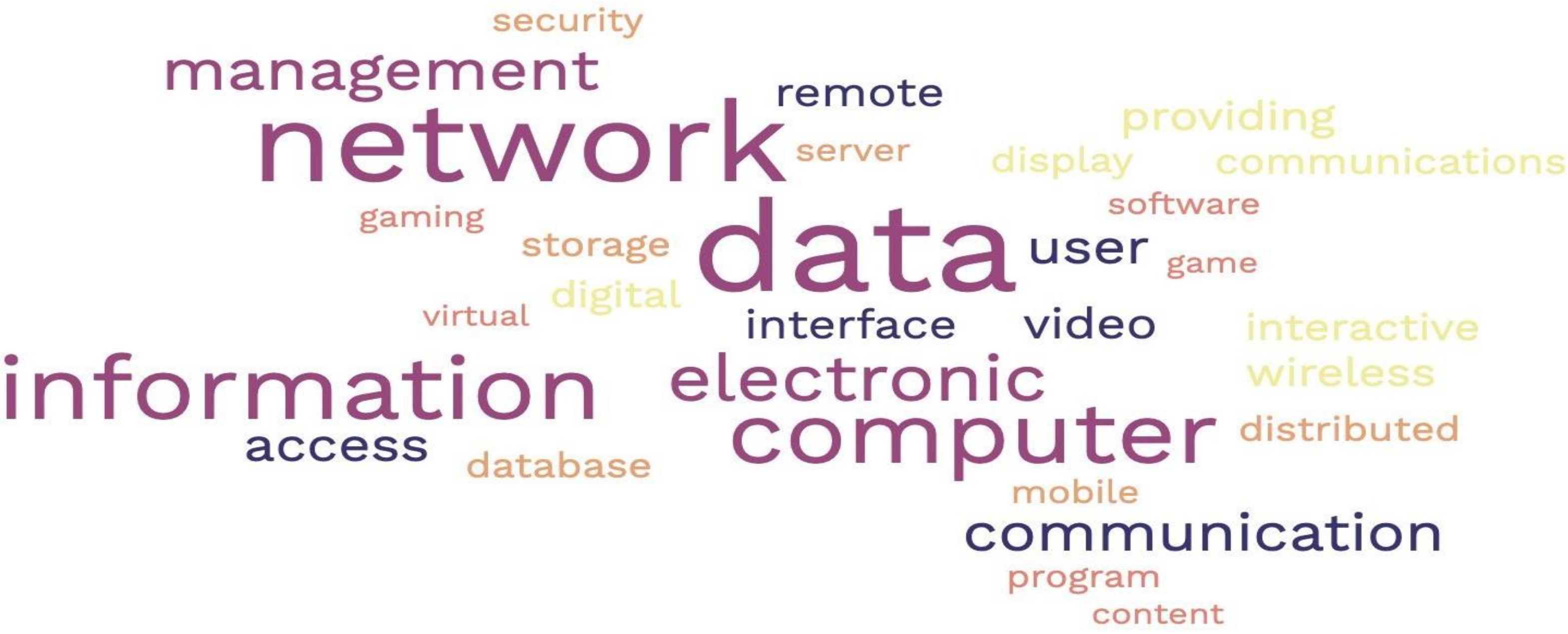
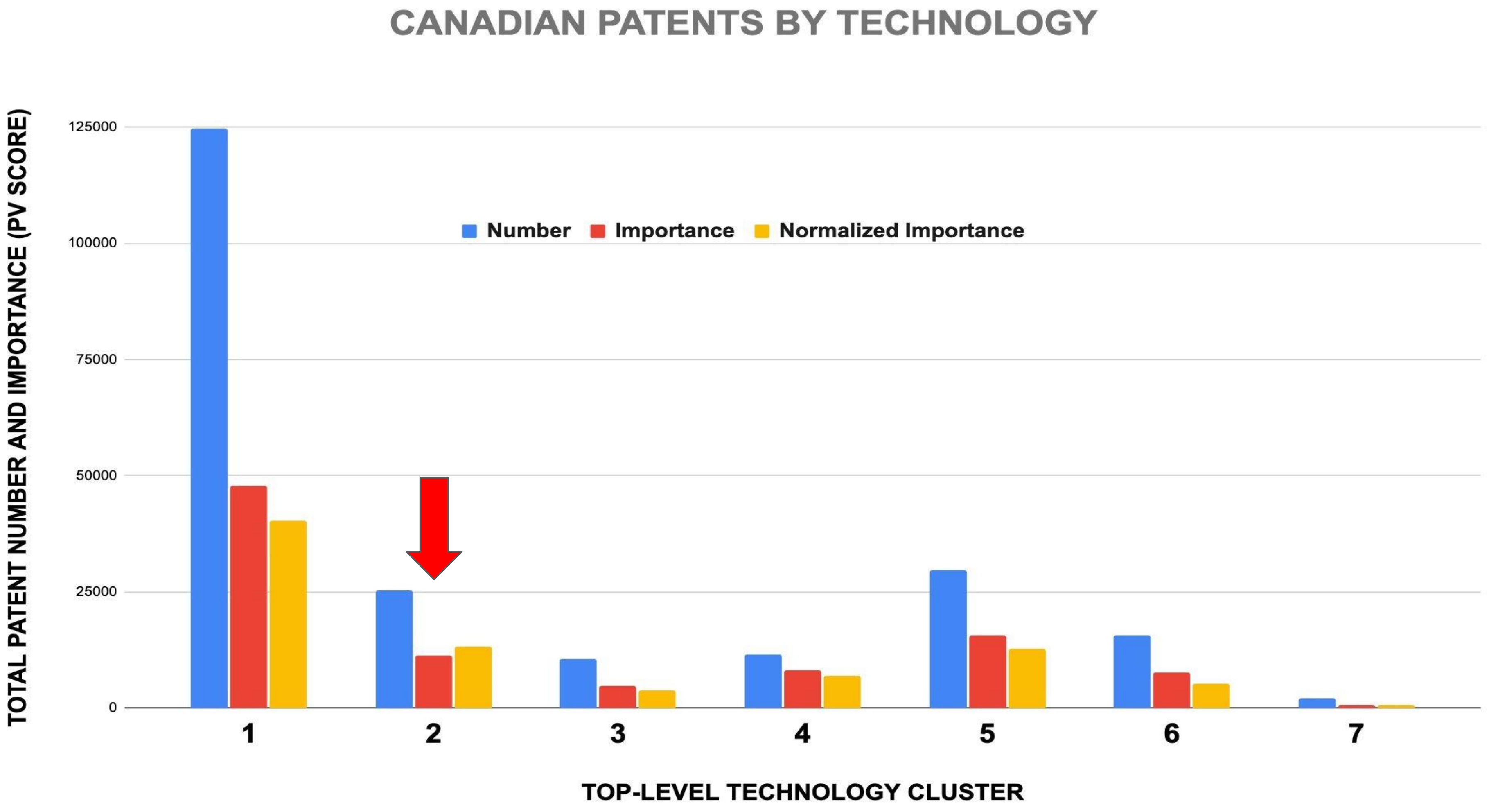
TOP-LEVEL TECHNOLOGY CLUSTER

CANADIAN IMPROVEMENT




CANADIAN PATENTS BY TECHNOLOGY
TOTAL PATENT NUMBER AND IMPORTANCE (PV SCORE)
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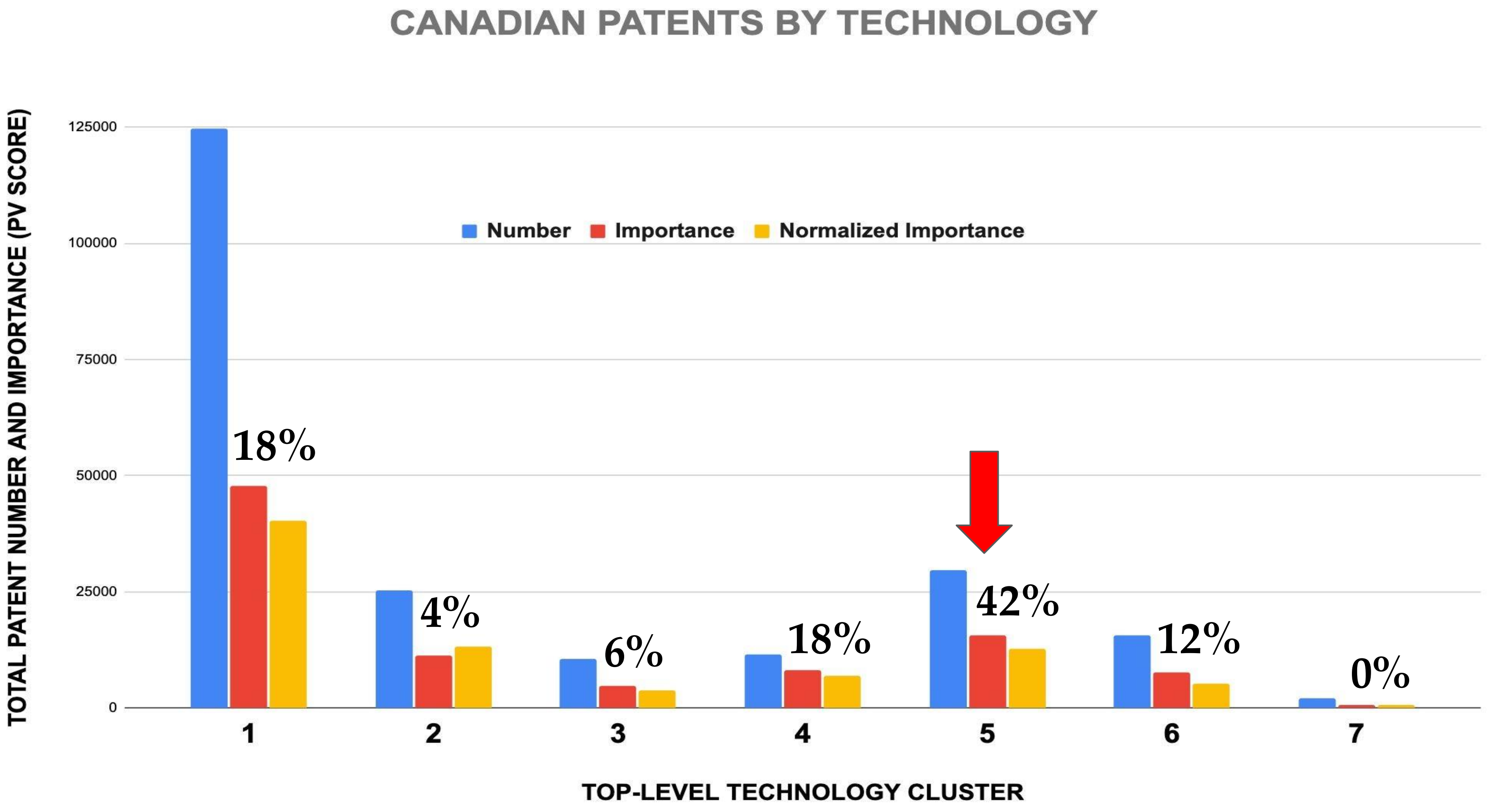
TOP-LEVEL TECHNOLOGY CLUSTER


CANADIAN PATENTS BY TECHNOLOGY
Number
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18%
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0%
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TOP-LEVEL TECHNOLOGY CLUSTER

PATENT ORIGINALITY (-1↔+1)

Article

Papers and patents are becoming less disruptive over time

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Check for updates

Michael Park[1], Erin Leahey[2] & Russell J. Funk[1]

Theories of scientific and technological change view discovery and invention as endogenous processes[1,2], wherein previous accumulated knowledge enables future progress by allowing researchers to, in Newton's words, 'stand on the shoulders of giants'[3–7]. Recent decades have witnessed exponential growth in the volume of new scientific and technological knowledge, thereby creating conditions that should be ripe for major advances[8,9]. Yet contrary to this view, studies suggest that progress is slowing in several major fields[10,11]. Here, we analyse these claims at scale across six decades, using data on 45 million papers and 3.9 million patents from six large-scale datasets, together with a new quantitative metric—the CD index[12]—that characterizes how papers and patents change networks of citations in science and technology. We find that papers and patents are increasingly less likely to break with the past in ways that push science and technology in new directions. This pattern holds universally across fields and is robust across multiple different citation- and text-based metrics[1,13–17]. Subsequently, we link this decline in disruptiveness to a narrowing in the use of previous knowledge, allowing us to reconcile the patterns we observe with the 'shoulders of giants' view. We find that the observed declines are unlikely to be driven by changes in the quality of published science, citation practices or field-specific factors. Overall, our results suggest that slowing rates of disruption may reflect a fundamental shift in the nature of science and technology.

Although the past century witnessed an unprecedented expansion of scientific and technological knowledge, there are concerns that innovative activity is slowing[18–20]. Studies document declining research productivity in semiconductors, pharmaceuticals and other fields[10,11]. Papers, patents and even grant applications have become less novel relative to prior work and less likely to connect disparate areas of knowledge, both of which are precursors of innovation[21,22]. The gap between the year of discovery and the awarding of a Nobel Prize has also increased[23,24], suggesting that today's contributions do not measure up to the past. These trends have attracted increasing attention from policymakers, as they pose substantial threats to economic growth, human health and wellbeing, and national security, along with global efforts to combat grand challenges such as climate change[25,26].

Numerous explanations for this slowdown have been proposed. Some point to a dearth of 'low-hanging fruit' as the readily available productivity-enhancing innovations have already been made[19,27]. Others emphasize the increasing burden of knowledge; scientists and inventors require ever more training to reach the frontiers of their fields, leaving less time to push those frontiers forward[18,28]. Yet much remains unknown, not merely about the causes of slowing innovative activity, but also the depth and breadth of the phenomenon. The decline is difficult to reconcile with centuries of observation by philosophers of science, who characterize the growth of knowledge as an endogenous process, wherein previous knowledge enables future discovery, a view captured famously in Newton's observation that if he had seen further, it was by 'standing on the shoulders of giants'[3]. Moreover, to date, the evidence pointing to a slowdown is based on studies of particular fields, using disparate and domain-specific metrics[10,11], making it difficult to know whether the changes are happening at similar rates across areas of science and technology. Little is also known about whether the patterns seen in aggregate indicators mask differences in the degree to which individual works push the frontier.

We address these gaps in understanding by analysing 25 million papers (1945–2010) in the Web of Science (WoS) (Methods) and 3.9 million patents (1976–2010) in the United States Patent and Trademark Office's (USPTO) Patents View database (Methods). The WoS data include 390 million citations, 25 million paper titles and 13 million abstracts. The Patents View data include 35 million citations, 3.9 million patent titles and 3.9 million abstracts. Subsequently, we replicate our core findings on four additional datasets—JSTOR, the American Physical Society corpus, Microsoft Academic Graph and PubMed—encompassing 20 million papers. Using these data, we join a new citation-based measure[12] with textual analyses of titles and abstracts to understand whether papers and patents forge new directions over time and across fields.

Measurement of disruptiveness

To characterize the nature of innovation, we draw on foundational theories of scientific and technological change[2,29,30], which distinguish between two types of breakthroughs. First, some contributions improve existing streams of knowledge, and therefore consolidate the status

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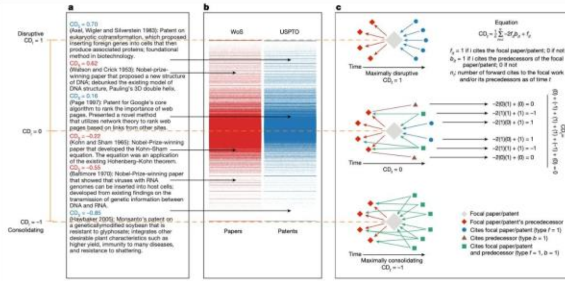


Fig. 1 | Overview of the measurement approach. This figure shows a schematic visualization of the CD index. a, CD index value of three Nobel Prize-winning papers[31,32,38] and three notable patents[39–41] in our sample, measured as of five years post-publication (indicated by CD_5). b, Distribution of CD_5 for papers from WoS (n = 24,659,076) between 1945 and 2010 and patents from Patents View (n = 3,912,353) between 1976 and 2010, where a single dot represents a paper or patent. The vertical (up–down) dimension of each 'strip' corresponds to values of the CD index (with axis values shown in orange on the left). The horizontal (left–right) dimension of each strip helps to minimize overlapping points. Darker areas on each strip plot indicate denser regions of the distribution (that is, more commonly observed CD_5 values). Additiona[l] details on the distribution of the CD index are given in Extended Data Fig. 1. c, Three hypothetical citation networks, where the CD index is at the maxim[um] disruptive value (CD_5 = 1), midpoint value (CD_5 = 0), and maximally consolidat[ing] value (CD_5 = −1). The panel also provides the equation for the CD index and a[n] illustrative calculation.

quo. Kohn and Sham (1965)[31], a Nobel-winning paper used established theorems to develop a method for calculating the structure of electrons, which cemented the value of previous research. Second, some contributions disrupt existing knowledge, rendering it obsolete, and propelling science and technology in new directions. Watson and Crick (1953)[32], also a Nobel winner, introduced a model of the structure of DNA that superseded previous approaches (for example, Pauling's triple helix). Kohn and Sham and Watson and Crick were both important, but their implications for scientific and technological change were different.

We quantify this distinction using a measure—the CD index[12]—that characterizes the consolidating or disruptive nature of science and technology (Fig. 1). The intuition is that if a paper or patent is disruptive, the subsequent work that cites it is less likely to also cite its predecessors; for future researchers, the ideas that went into its production are less relevant (for example, Pauling's triple helix). If a paper or patent is consolidating, subsequent work that cites it is also more likely to cite its predecessors; for future researchers, the knowledge upon which the work builds is still (and perhaps more) relevant (for example, the theorems Kohn and Sham used). The CD index ranges from −1 (consolidating) to 1 (disruptive). We measure the CD index five years after the year of each paper's publication (indicated by CD_5, see Extended Data Fig. 1 for the distribution of CD_5 among papers and patents and Extended Data Fig. 2 for analyses using alternative windows)[33]. For example, Watson and Crick and Kohn and Sham both received over a hundred citations within five years of being published. However, the Kohn and Sham paper has a CD_5 of −0.22 (indicating consolidation), whereas the Watson and Crick paper has a CD_5 of 0.62 (indicating disruption). The CD index has been validated extensively in previous research, including through correlation with expert assessments[12,34].

Declining disruptiveness

Across fields, we find that science and technology are becoming l[ess] disruptive. Figure 2 plots the average CD_5 over time for papers (Fig. [2a]) and patents (Fig. 2b). For papers, the decrease between 1945 and 2[010] ranges from 91.9% (where the average CD_5 dropped from 0.52 in 1[945] to 0.04 in 2010 for 'social sciences') to 100% (where the average [CD_5] decreased from 0.36 in 1945 to 0 in 2010 for 'physical sciences'); for p[at]ents, the decrease between 1980 and 2010 ranges from 78.7% (where average CD_5 decreased from 0.30 in 1980 to 0.06 in 2010 for 'comput[ers] and communications') to 91.5% (where the average CD_5 decreased fr[om] 0.38 in 1980 to 0.03 in 2010 for 'drugs and medical'). For both pap[ers] and patents, the rates of decline are greatest in the earlier parts of [the] time series, and for patents, they appear to begin stabilizing betw[een] the years 2000 and 2005. For papers, since about 1980, the rat[e of] decline has been more modest in 'life sciences and biomedicine' [and] physical sciences, and most marked and persistent in social scien[ces] and 'technology'. Overall, however, relative to earlier eras, recent pap[ers] and patents do less to push science and technology in new directio[ns]. The general similarity in trends we observe across fields is notewor[thy] in light of 'low-hanging fruit' theories[19,27], which would probably pre[dict] greater heterogeneity in the decline, as it seems unlikely fields wo[uld] 'consume' their low-hanging fruit at similar rates or times.

Linguistic change

The decline in disruptive science and technology is also observa[ble] using alternative indicators. Because they create departures fr[om] the status quo, disruptive papers and patents are likely to introd[uce] new words (for example, words used to create a new paradigm mi[ght] differ from those that are used to develop an existing paradigm)[...]

Article

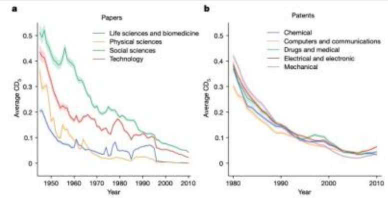


Fig. 2 | Decline of disruptive science and technology. a,b, Decline in CD_5 over time, separately for papers (a, n = 24,659,076) and patents (b, n = 3,912,353). For papers, lines correspond to WoS research areas; from 1945 to 2010 the magnitude of decline ranges from 91.9% (social sciences) to 100% (physical sciences). For patents, lines correspond to National Bureau of Economic Research (NBER) technology categories; from 1980 to 2010 the magnitude of decline ranges from 93.5% (computers and communications) to 96.4% (drugs and medical). Shaded bands correspond to 95% confidence intervals. As we elaborate in the Methods, this pattern of decline is robust to adjustment for confounding from changes in publication, citation and authorship practices over time.

Therefore, if disruptiveness is declining, we would expect a decline in the diversity of words used in science and technology. To evaluate this, Fig. 3a,d documents the type-token ratio (that is, unique/total words) of paper and patent titles over time (Supplementary Information section 1). We observe substantial declines, especially in the earlier periods, before 1970 for papers and 1990 for patents. For paper titles (Fig. 3a), the decrease (1945–2010) ranges from 76.5% (social sciences) to 88% (technology); for patent titles (Fig. 3d), the decrease (1980–2010) ranges from 32.5% (chemical) to 81% (computers and communications). For paper abstracts (Extended Data Fig. 3a), the decrease (1992–2010) ranges from 23.1% (life sciences and biomedicine) to 38.9% (social sciences); for patent abstracts (Extended Data Fig. 3b), the decrease (1980–2010) ranges from 21.5% (mechanical) to 73.2% (computers and communications). In Fig. 3b,e, we demonstrate that these declines in word diversity are accompanied by similar declines in combinatorial novelty; over time, the particular words that scientists and inventors use in the titles of their papers and patents are increasingly likely to have been used together in the titles of previous work. Consistent with these trends in language, we also observe declining novelty in the combinations of previous work cited by papers and patents, based on a previously established measure of 'atypical combinations'[14] (Extended Data Fig. 4).

The decline in disruptive activity is also apparent in the specific words used by scientists and inventors. If disruptiveness is declining, we reasoned that verbs alluding to the creation, discovery or perception of new things should be used less frequently over time, whereas verbs alluding to the improvement, application or assessment of existing things may be used more often[35,36]. Figure 3 shows the most common verbs in paper (Fig. 3c) and patent titles (Fig. 3f) in the first and last decade of each sample (Supplementary Information section 2). Although precisely and quantitatively characterizing words as 'consolidating' or 'disruptive' is challenging in the absence of context, the figure highlights a clear and qualitative shift in language. In the earlier decades, verbs evoking creation (for example, 'produce', 'form', 'prepare' and 'make'), discovery (for example, 'determine' and 'report') and perception (for example, 'measure') are prevalent in both paper and patent titles. In the later decades, however, these verbs are almost completely displaced by those tending to be more evocative of the improvement (for example, 'improve', 'enhance' and 'increase'), application (for example, 'use' and 'include') or assessment (for example, 'associate', 'mediate' and 'relate') of existing scientific and technological knowledge and artefacts. Taken together, these patterns suggest a substantive shift in science and technology over time, with discovery and invention becoming less disruptive in nature, consistent with our results using the CD index.

Conservation of highly disruptive work

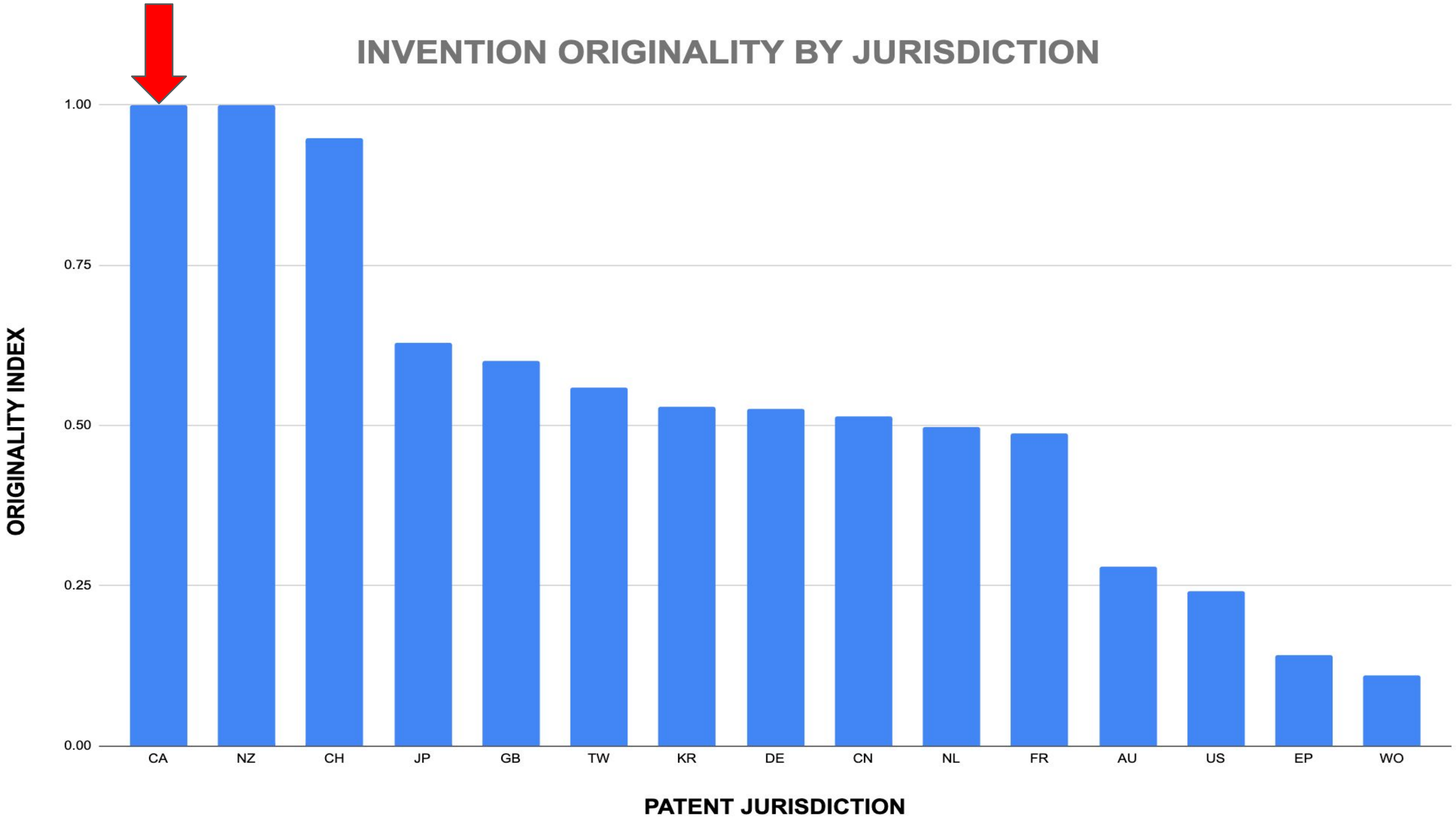
The aggregate trends we document mask considerable heterogeneity in the disruptiveness of individual papers and patents and remarkable stability in the absolute number of highly disruptive works (Methods and Fig. 4). Specifically, despite large increases in scientific productivity, the number of papers and patents with CD_5 values in the far right tail of the distribution remains nearly constant over time. This 'conservation' of the absolute number of highly disruptive papers and patents holds despite considerable churn in the underlying fields responsible for producing those works (Extended Data Fig. 5, inset). These results suggest that the persistence of major breakthroughs—for example, measurement of gravity waves and COVID-19 vaccines—is not inconsistent with slowing innovative activity. In short, declining aggregate disruptiveness does not preclude individual highly disruptive works.

Alternative explanations

What is driving the decline in disruptiveness? Earlier, we suggested our results are not consistent with explanations that link slowing innovative activity to diminishing 'low-hanging fruit'. Extended Data Fig. 5 shows that the decline in disruptiveness is unlikely to be due to other field-specific factors by decomposing variation in CD_5 attributable to field, author and year effects (Methods).

Declining rates of disruptive activity are unlikely to be caused by the diminishing quality of science and technology[22,37]. If they were, then the patterns seen in Fig. 2 should be less visible in high-quality work. However, when we restrict our sample to articles published in premier publication venues such as *Nature*, *Proceedings of the National Academy of Sciences* and *Science* or to Nobel-winning discoveries[38] (Fig. 5), the downward trend persists.

Furthermore, the trend is not driven by characteristics of the WoS and UPSTO data or our particular derivation of the CD index; we observe similar declines in disruptiveness when we compute CD_5 on papers


INVENTION ORIGINALITY BY JURISDICTION
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AU
US
EP
WO
PATENT JURISDICTION

CONCLUSIONS

- Major observations
    - Patent data growing steadily and rapidly
    - Interesting changes have been occurring at various depths in the network
    - Flow of information (inferred from citations) among countries is evolving rapidly
    - Canada is one of top patent producers both in volume and importance
    - Largest portfolios of Canadian patents largely owned by non-Canadian firms
    - Canada generally excels at medical devices and is rapidly improving in software and telecommunications
    - Canada is especially strong (sometimes even dominant) in specific technology areas, especially biopharmaceuticals
    - Surprise: Canadian inventions are extremely original!
- Network science is powerful method for gaining insights into worldwide and Canadian patent systems
- We welcome questions and comments

Treasury Board of Canada Secretariat | Secrétariat du Conseil du Trésor du Canada

Statistique Canada | Statistics Canada

Canada

Canadian Trademarks Research Database

Rashid Nikzad, Treasury Board of Canada Secretariat

Mohamed Ouardi, Treasury Board of Canada Secretariat

Francis Demers, Statistics Canada

Daouda Sylla, Treasury Board of Canada Secretariat

6th Annual IP Data & Research Conference

Ottawa, May 31, 2023

* Disclaimer- The views presented in this study are of the authors only and do not represent those of the Treasury Board of Canada Secretariat, Statistics Canada, and/or Government of Canada

Background

- Linked trademarks data to the Statistics Canada's micro business data to better measure innovation activities
- This database will complement the patent database and other firm-level performance indicators
- The project is conducted as part of the Treasury Board of Canada Secretariat (TBS)-Statistics Canada's partnership to assess the impact of Business Innovation and Growth Support (BIGS) program

What is a trademark?

- A trademark is a sign or combination of signs used or proposed to be used by a person to distinguish their goods or services from those of others.
- Trademarks are the most widely used intellectual property right by firms across all economic sectors (WIPO, 2013)
- A trademark could be registered or unregistered
- Recently, trademarks have attracted attention to measure innovation. They may be used as:
    - Direct measure of innovation/firm’s performance
    - Indirect measure of innovation/firm’s performance
    - Complement to research and development (R&D) expenditures and patent statistics as the most common measures of innovation

Linking Trademarks to B-LFE and BIGS

- TM-Link is an international dataset in which similar trademarks from different countries
  - Five jurisdictions of Australia, New Zealand, Canada, European Union, the United States
  - Worldwide Canadian trademarks applications identified
  - Canadian Intellectual Property Office (CIPO) data was used to complement data for Canadian applicants in Canada
- The Business Linkable File Environment (B-LFE) is an environment in which Statistics Canada's business microdata are linked from different administrative and survey sources
  - The B-LFE includes enterprise-level data such as R&D expenditures and performance indicators
- Business Innovation and Growth Support (BIGS) support database covers all federal government activities that support business innovation and growth since 2007

Methodology

- TM-Link applicants in 1998-2019 with at least one Canadian address from five jurisdictions were linked to the LFE
- Probabilistic matching of TM-Link applicants to Business Register (BR) enterprises based on common business name, address, province, country and postal code
  - Match Rate: 89.5%
- Some reasons that can explain non match:
  - missing or poor-quality information on some specific record
  - time lags between the registration of the business and the creation of the business number in the BR
- Given the high match rate, the impact of non match on the results is negligeable

Methodology

- Linkage of TM-Link – BR matched applicants to the BR-LFE
  - Business Register (industrial classification, province of operations, country of control, business age and type of organization)
  - General Index of Financial Information and Statement of account for current source deductions.
  - T661 form on Scientific Research and Experimental Development Expenditures (SR&ED) claim and the Business Innovation and Growth Support (BIGS)
    - Draw a profile of trademark applicants supported by the federal government in the form of R&D tax credits or direct innovation support.

Applicants by year and IP Office (rounded to nearest 5)

- The matching rate is about 90%, consistent across all years and IP offices
- Between 30K to 40K unique applicants (enterprises) per year

Application Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	31,995	36,215	39,260	32,305	30,960	31,710	31,460	33,180	34,680	35,535	33,900
Matching rate	88.8%	88.6%	88.6%	88.8%	89.9%	89.0%	89.9%	89.6%	90.3%	89.9%	90.2%

Application Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total	30,835	33,095	34,300	34,565	33,950	33,560	35,255	36,270	38,930	40,565	34,710
Matching rate	90.0%	89.6%	89.2%	89.3%	89.2%	89.9%	90.3%	89.8%	89.8%	89.5%	88.8%

- Most Canadian enterprises file trademarks in Canada and in the United States

IP Office	Total	Matching rate
Australia	8,150	91.18%
Canada	545,745	90.74%
European Union	17,055	96.01%
New Zealand	2,225	94.47%
United States	184,055	85.08%

Applicants by employment and revenue size (rounded to nearest 5)

- The following tables are aggregated for 2007-2019
- Most applicants have fewer than 100 employees or the employee number is not known, and have less than $10,000,000 of revenue or revenue is not known
- Note that these numbers are unique applicants (enterprises) regardless of the number of applications

Employment size	Count	Percentage
0 to 99	92,845	54.70%
100 to 249	3,845	2.27%
250 to 499	1,515	0.89%
500 and more	2,040	1.20%
Unclassified	69,485	40.94%
Total	169,735	100.00%

Revenue size	Count	Percentage
Less than $0	1,055	0.62%
$0 to $99,999	30,165	17.77%
$100,000 to $999,999	37,425	22.05%
$1,000,000 to $9,999,999	29,905	17.62%
$10,000,000 and more	12,895	7.60%
Unclassified	58,290	34.34%
Total	169,735	100.00%

Applicants by province, R&D, exports (rounded to nearest 5)

- Most applicants are from Ontario, followed by Quebec, British Columbia, and Alberta

Province (unique)	Count	Percentage
ON	51,810	43.31%
QC	24,340	20.35%
AB	12,115	10.13%
BC	21,960	18.36%
MB, SK	4,695	3.92%
NB, NL, NS, PE	4,135	3.46%
NT, NU, YT	100	0.08%
Unclassified	470	0.39%
Total	119,625	100.00%

- BIGS, Scientific Research and Experimental Development (SR&ED), R&D, and exporter:

Total (unique enterprise)	In BIGS	In SR&ED	In Both BIGS and SR&ED	R&D performer	Exporter
119,630	17,440	16,660	8,490	15,580	20,610
Percentage of total	14.58%	13.93%	7.10%	13.02%	17.23%

Most applicants are in the service sector, in particular 54 (rounded to nearest 5)

Industry	NAICS	Count	Percentage
Agriculture, forestry, fishing and hunting	11	1,850	1.5%
Mining, quarrying, and oil and gas extraction	21	350	0.3%
Utilities	22	120	0.1%
Construction	23	3,960	3.3%
Manufacturing	31-33	9,375	7.8%
Wholesale trade	41	9,610	8.0%
Retail trade	44-45	11,285	9.4%
Transportation and warehousing	48-49	2,245	1.9%
Information and cultural industries	51	3,425	2.9%
Finance and insurance	52	3,440	2.9%
Real estate and rental and leasing	53	9,140	7.6%
Professional, scientific and technical services	54	21,315	17.8%
Management of companies and enterprises	55	2,605	2.2%
Administrative and support, waste management and remediation services	56	5,310	4.4%
Educational services	61	2,655	2.2%
Health care and social assistance	62	4,145	3.5%
Arts, entertainment and recreation	71	4,125	3.4%
Accommodation and food services	72	4,010	3.4%
Other services (except public administration)	81	7,950	6.6%
Public administration	91	670	0.6%
Unclassified		12,040	10.1%
Total		119,625	100.0%

Summary of the findings

- Canadian Trademarks Research Database complements other innovation indicator databases such as the patent database, etc.
- It covers 1998 to 2019
- The matching rate is about 90%, consistent across all years and IP offices
- As expected, most Canadian enterprises file trademarks in Canada, followed by the United States
- Most applicants have fewer than 100 employees (54.7%) and less than $10,000,000 of annual revenue (58.1%)
  - 40.9% lack an employment classification and 34.3% a revenue classification
- Most applicants are from Ontario (43.3%), followed by Quebec (20.4%), British Columbia (18.4%), and Alberta (10.1%)
- Most applicants are in the service sector (unlike patent applicants that are in the manufacturing sector)

Next steps

- The Canadian Trademarks Research Database can be used to address various research questions
- The project may later be extended to include industrial design data (patent data already linked)

- Some questions include:
    - How do trademarks complement innovation and firm's performance?
    - Can trademarks measure innovations that cannot be captured by other indicators such as patent and R&D expenditures?
    - How can trademarks help enterprises secure financial resources?
    - How can trademarks help enterprises in their market performance?
    - What does the timing of trademark filing reveal about the innovation process?
    - Is bundling of trademarks with other intellectual property rights a scale-up indicator?

INNOVATING FOR HEALTH

THE ROLE OF HEALTH INSTITUTIONS IN DRIVING COMMERCIALIZATION OF BIOMEDICAL RESEARCH/INTELLECTUAL PROPERTY FOR IMPROVED HEALTHCARE DELIVERY

Question

Data

Gap

Relevance

Heidi Walsh Sampson
Morris Odeh

DALHOUSIE UNIVERSITY
MANAGEMENT

6th Annual Data &IP Conference
Canadian Intellectual Property Office
Centre for International Governance Innovation
May 31, 2023

What is the role of health institutions in Driving the Commercialization of Biomedical Research /Intellectual Property for Improved Healthcare Delivery?

Commercialization of biomedical research/IP is the long and complex process that takes inventions from labs to the marketplace and eventually the patient's bedside.

Some life-saving biomedical research/ IP does not survive the journey due to the **pre-commercialization gap**

Pre-commercialization Gap

TTOs

HealthAuthorities

Health Institutions

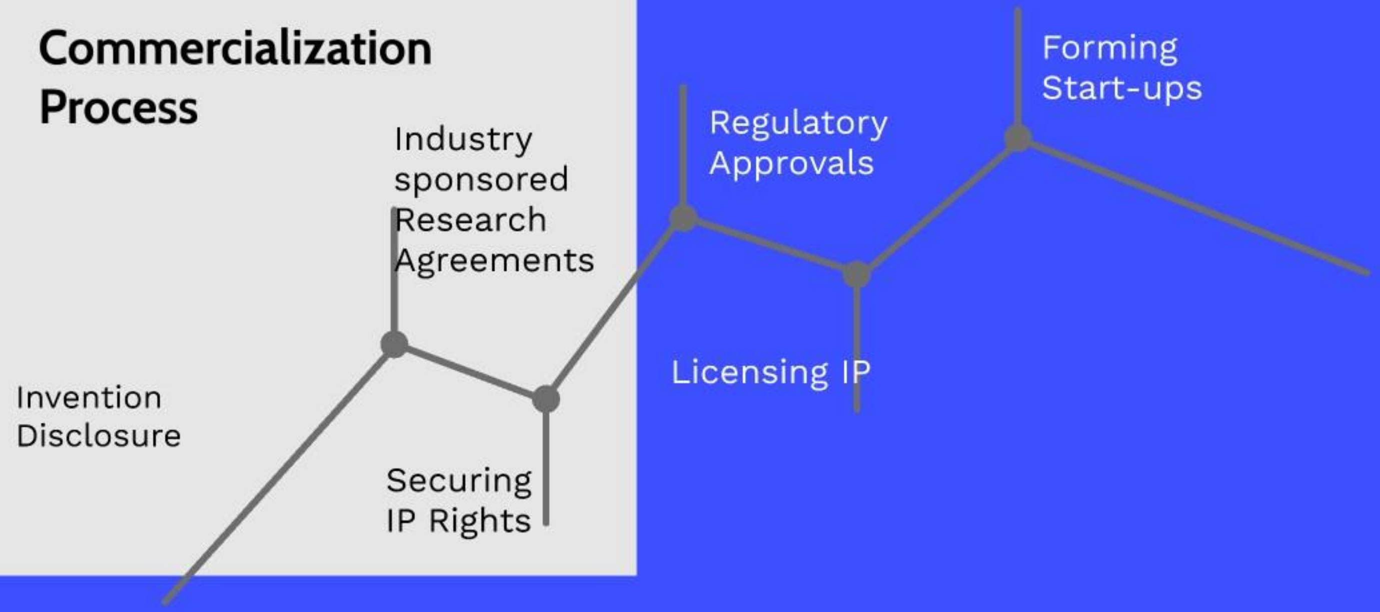
Pre-Commercialization Gap

- a structural breakdown in the innovation chain after the point where the discovery research has stopped and the point where it is commercially viable for the private sector willing to invest in translating the discovery research into a marketable product.

Association of Canadian Academic Healthcare Organizations, "Our Paths to Prosperity…A Policy Road Map for Canada's Health Research, Innovation & Commercialization Enterprise" (April 2008), 2.

Valley of Death

Commercialization Process



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Milestones

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Some life-saving biomedical research/ IP does not survive the journey due to the **pre-commercialization gap**

Tech Transfer Offices

Often the natural Commercialization Lead responsible for new inventions involving cross-appointed faculty, university researchers and students.

This research poses the question of whether this is the most efficient way to develop biomedical research/IP.

U15 Members

Our Members

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Health Authorities

- Trend toward active IP management
- Independent activity outside of collaboration with universities with med schools
- IP policy review

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Commercialization within health institutions

Hospitals with commercialization and BD teams.

- Active patent portfolios
- Development of inhouse expertise in:
  - patent management
  - business development
  - technology management
  - IP licensing

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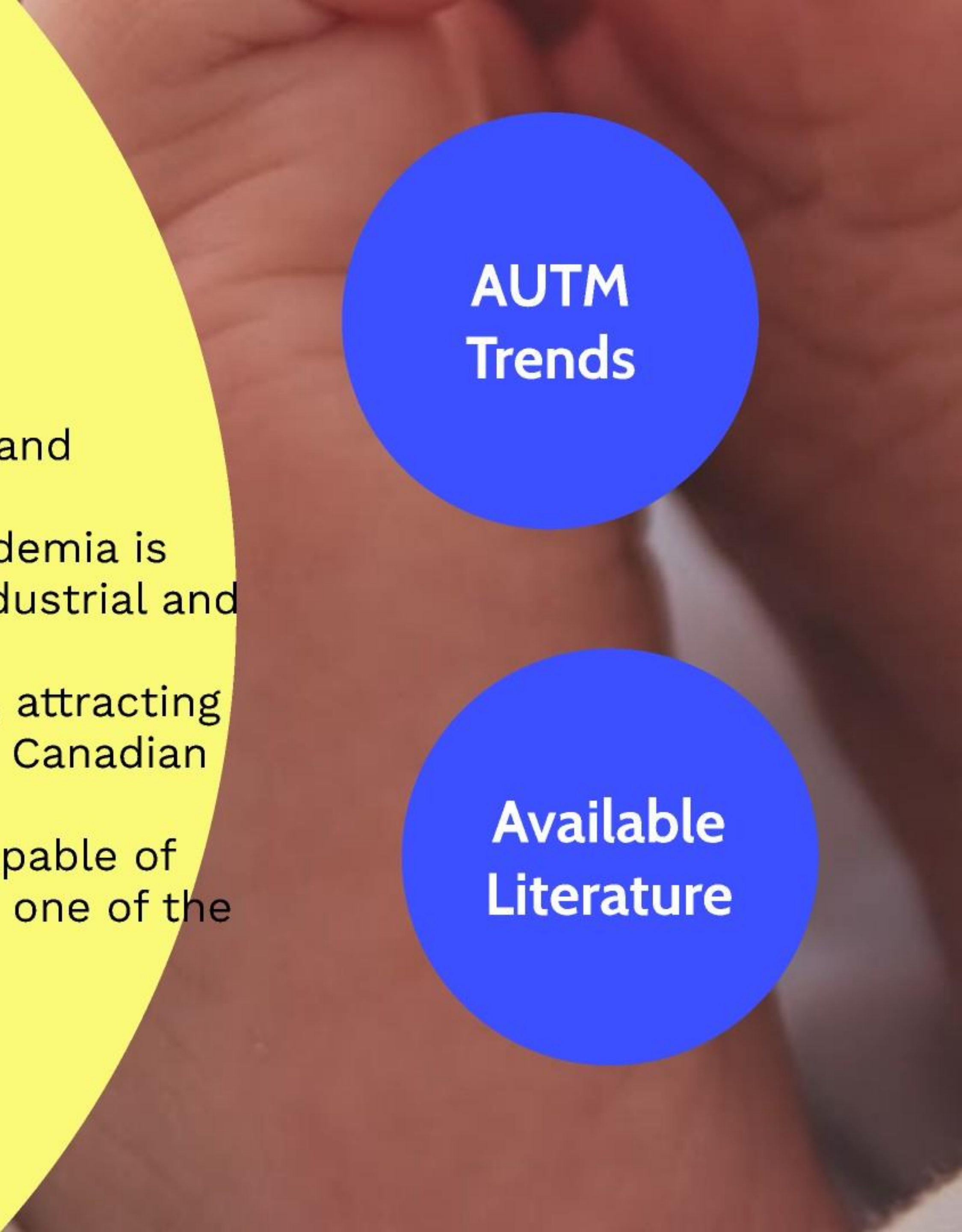
Intellectual Property and Technology Transfer:Promoting Best Practices

Report of the Standing Committee on Industry, Science and Technology, November 2017

- transactions in which knowledge developed in academia is communicated to firms in the private sector for industrial and commercial purposes
- Cited IP laws as critical to encouraging innovation, attracting investment and supporting other key drivers of the Canadian economy.
- Cited the lack of reliable and useful information capable of supporting policy-making and economic activity as one of the greates obstacles to tech transfer in Canada



Data Trends in AUTM

- Inconsistent # reporting
- Not comprehensive
- Variability in
    - $ raised
    - % of global numbers

Data

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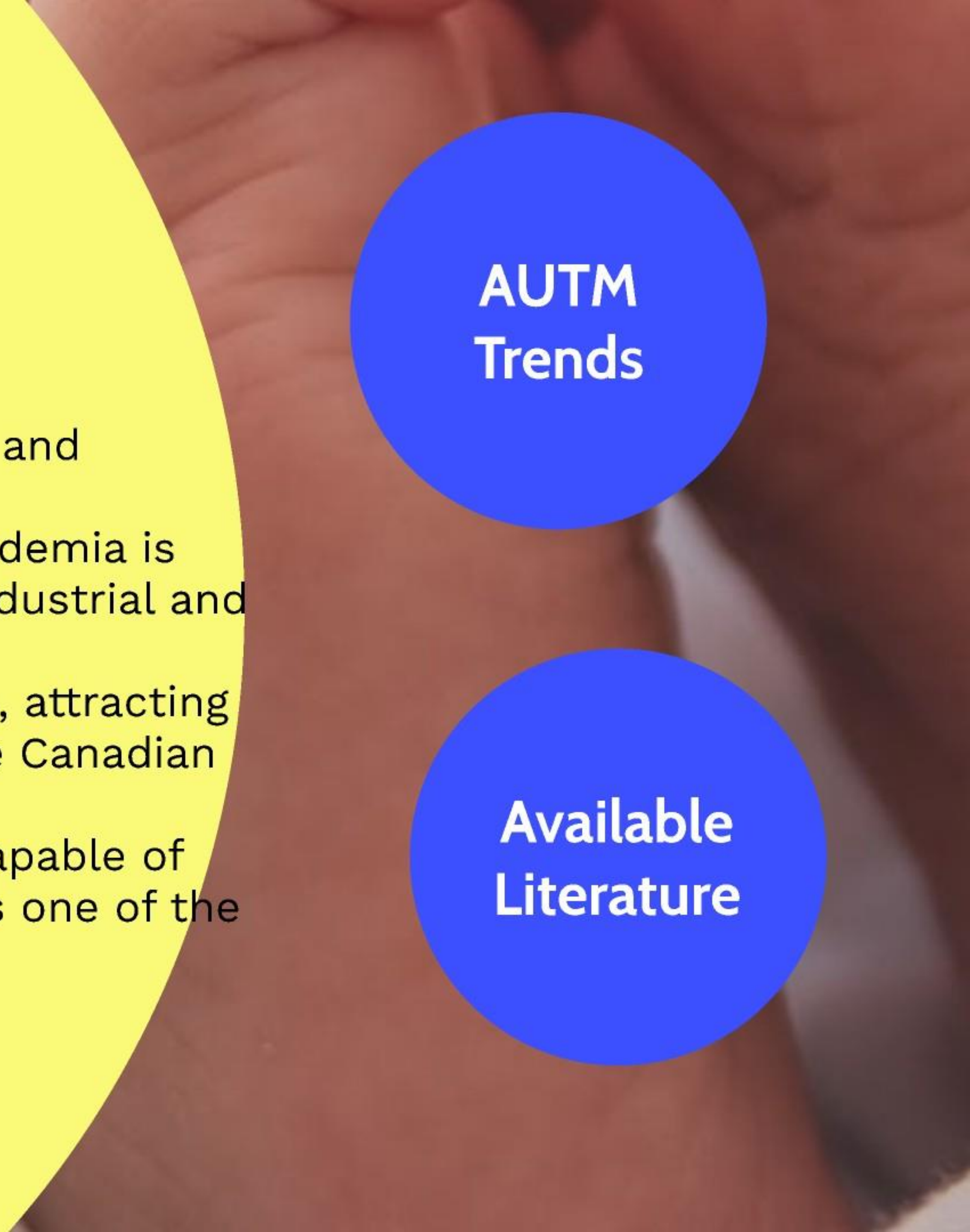

AUTM Trends

Available Literature

Literature Review of Commercialization Activities led by Health Institutes/ Hospitals

- Available literature focuses on the commercialization of IP between academia/industry
- A preliminary search of PROSPERO,MEDLINE, and JBI Database of Systematic Reviews and Implementation Reports revealed no current or in-progress reviews on the topic

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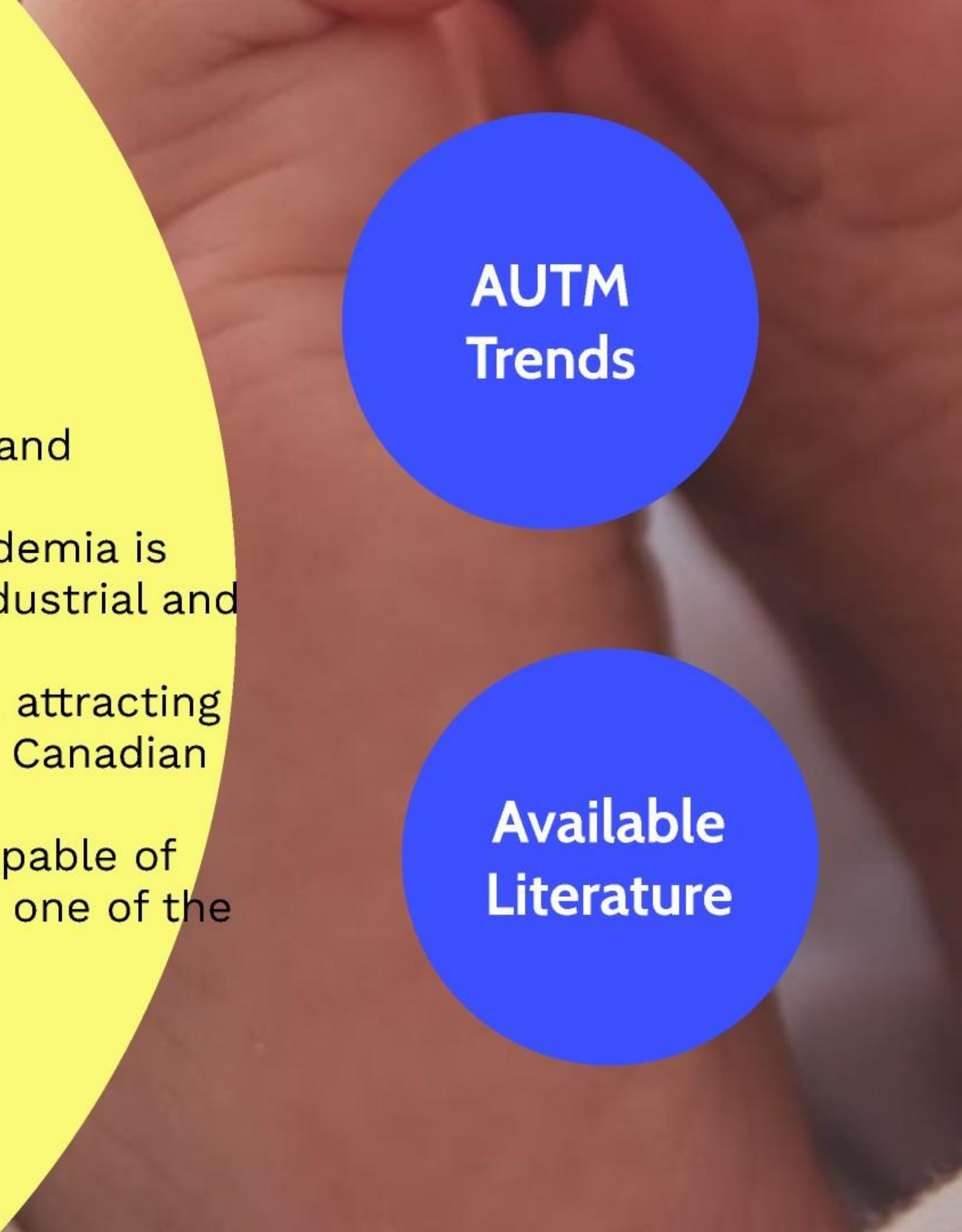

AUTM Trends

Available Literature

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Research Gap

Scoping Review

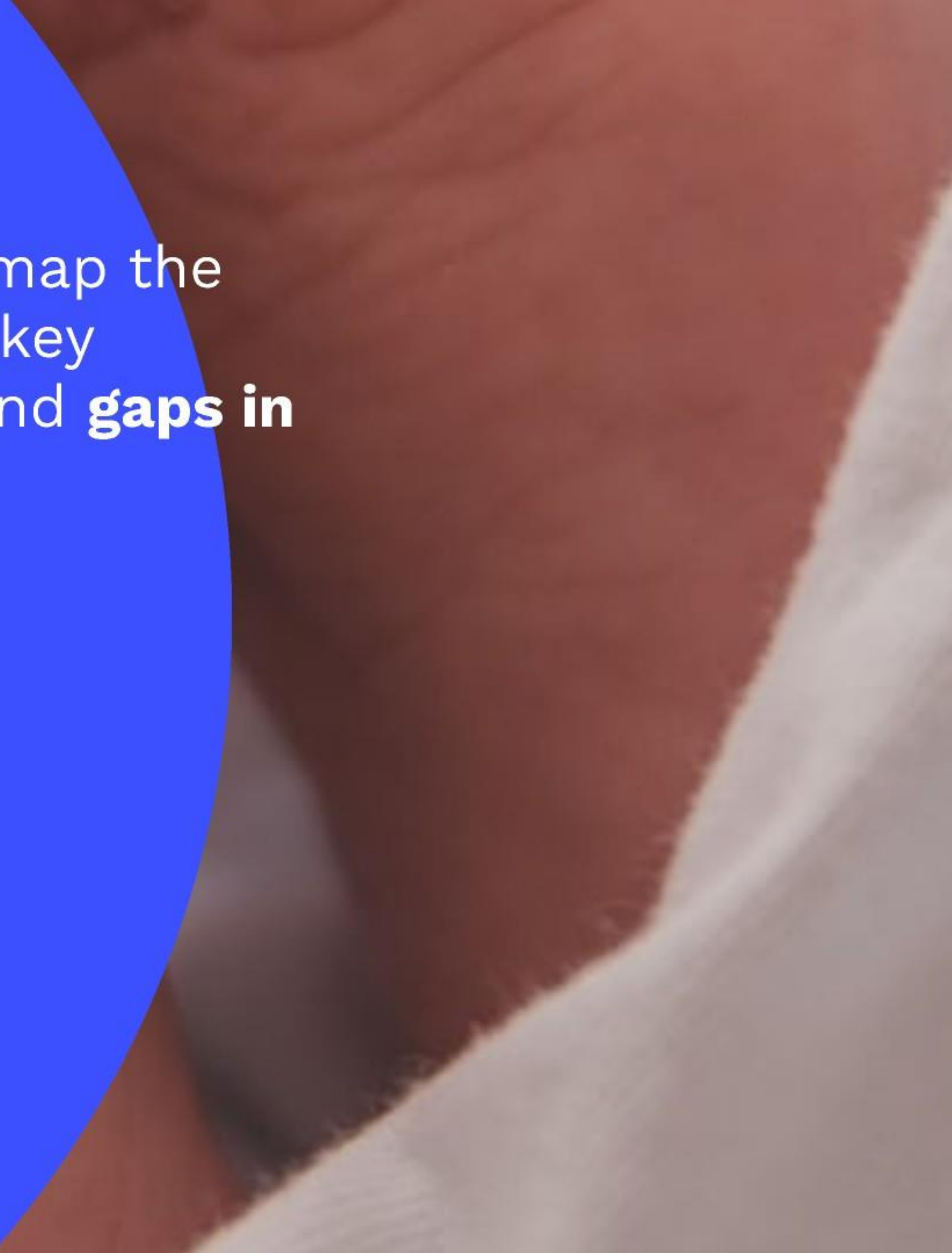
Review Questions:

1) What are the roles of health institutions in advancing the commercialization of biomedical research/IP

2) How can the roles be implemented to improve better health outcomes

Scoping Reviews

"exploratory projects that systematically map the literature available on a topic, identifying key concepts, theories, sources of evidence and **gaps in the research**"
https://cihr-irsc.gc.ca/e/41382.html



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Why this matters

The healthcare system across Canada is in crisis. If healthcare were a patient........

Calls for privatization threaten the universal coverage central to Medicare system.

Alternative ways to improve both equitable access and delivery of healthcare in Canada is paramount.

Reimagining the role of healthcare institutions in commercializing Biomedical Research/IP may be part of the solution.

It would be on life support

Compared to other healthcare systems, Canada's healthcare system ranks poorly on:

- Access to timely care
- Efficient administration and delivery of healthcare
- equity

https://infogram.com/mirror-mirror-2021-exhibit-6-1hzj4o3jkeq034p

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Bioscience Sector

The ACAHO stated that health research, innovation, and commercialization can leverage publicly-funded Medicare platform to enhance the health of Canadians, foster cost-effective healthcare delivery, and promote sustained economic growth.

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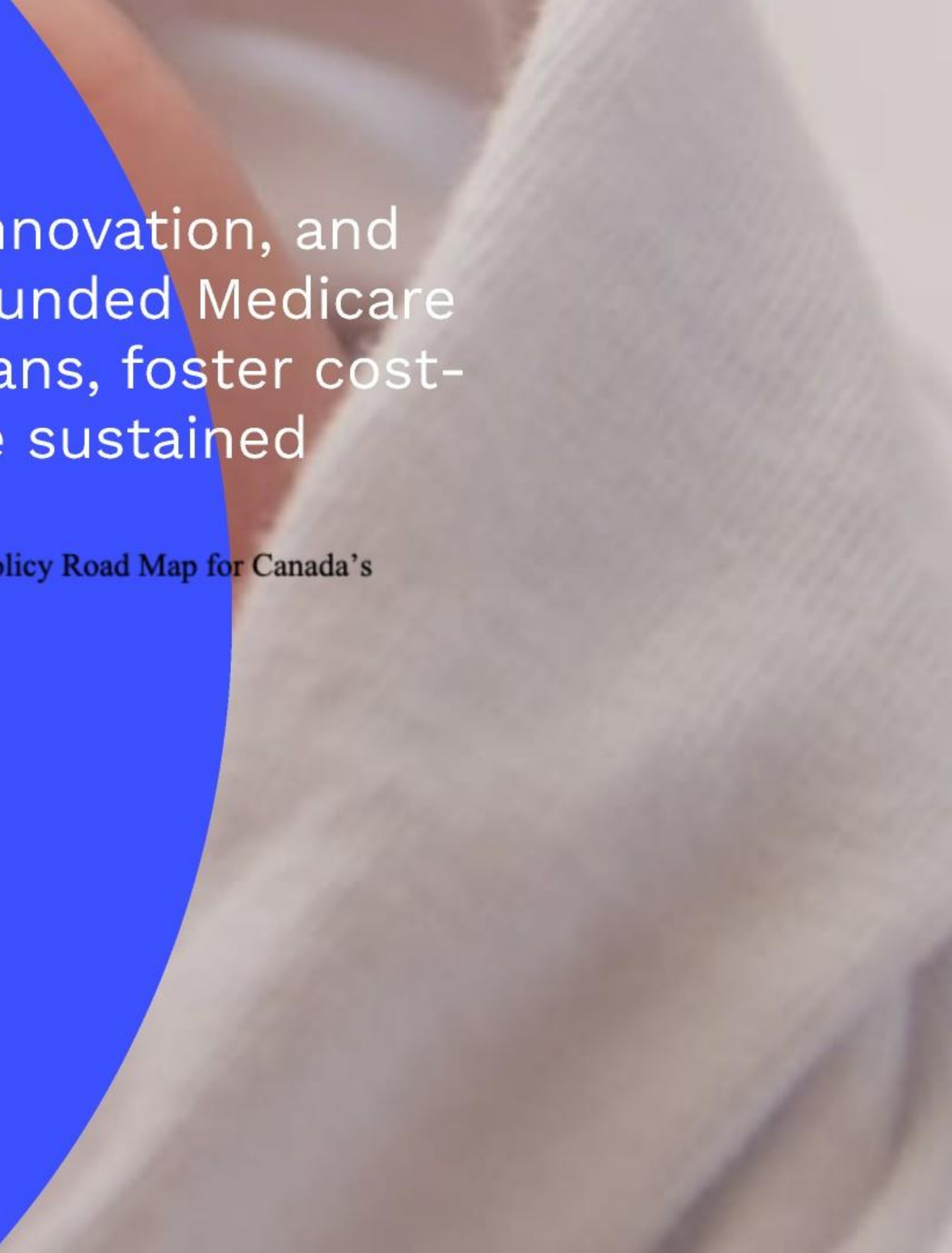

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We gratefully acknowlege the support of

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Mitacs

Sophie Moryto, Student-at-law, Schulich School of Law, Dalhousie University

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