Quantitative Study on the Dynamic Relationship between Scientific Research and Health Demand: A Case Study of Neurological Diseases (Postprint)

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Date: 2023-04-01T15:51:26+00:00

Abstract

[Purpose/Significance] Advances in science and technology are crucial means for safeguarding human life and enhancing well-being. Quantitatively investigating the dynamic relationship between scientific research and health needs can provide valuable references for research planning and resource allocation. [Method/Process] Using neurological diseases—one of the world's major causes of disability and mortality—as a case study, this research employs scientific literature data from 2000-2019, multiple disease burden indicators (Disability-Adjusted Life Years, mortality, research dependency burden), and the Human Development Index. Based on a constructed quantitative analytical framework for the relationship between scientific research and health needs, it examines the matching, correlation, and regression relationships between neurological disease burden and research output. [Results/Conclusion] The study reveals that over the past two decades, both the burden of neurological diseases and research literature output have exhibited upward trends globally. Overall, the scientific community has allocated relatively adequate attention to such diseases, though research efforts for certain conditions (e.g., migraine) remain comparatively insufficient. From the perspective of countries at different development levels, the burden of neurological diseases is primarily concentrated in very high-development countries, which also represent the core research force in addressing this burden. At the specific disease level, very high-development countries demonstrate weaker research attention toward diseases with relatively higher burdens in low- and middle-development countries (e.g., epilepsy). Regression analysis results demonstrate a significant positive correlation between disease burden and literature output, indicating that increases in disease burden positively influence related literature output. Compared with Disability-Adjusted Life Years, the more direct mortality indicator exerts a stronger effect on scien-

tific literature output. Furthermore, this study identifies the current limitations of the innovative indicator "research dependency burden" and proposes relevant recommendations based on the empirical results.

Full Text

Preamble

ChinaXiv Collaborative Journal
Volume 66, Issue 10, May 2022

A Quantitative Study on the Dynamic Relationship Between Scientific Research and Health Needs: Taking Neurological Diseases as an Example

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Abstract: [Purpose/Significance] The advancement of science and technology serves as a crucial means to safeguard human life and enhance well-being. Quantitatively exploring the dynamic relationship between scientific research and health needs can provide valuable insights for research planning and resource allocation. [Method/Process] Using neurological diseases—one of the world's major causes of disability and mortality—as a case study, this paper constructs a quantitative analytical framework for the relationship between scientific research and health needs. Based on scientific literature data from 2000–2019, multiple disease burden indicators (disability-adjusted life years, deaths, and research-dependent fraction of disease burden), and the Human Development Index, we examine the alignment, correlation, and regression relationships between neurological disease burden and research output. [Result/Conclusion] The study reveals that over the past two decades, both the burden of neurological diseases and related literature output have increased globally. Overall, the scientific community has devoted adequate attention to these diseases, though some conditions (e.g., migraine) remain relatively understudied. From the perspective of countries at different development levels, the disease burden is concentrated in very-high-HDI countries, which also constitute the core research force. However, very-high-HDI countries show weaker research attention toward diseases with relatively high burdens in low- and medium-HDI countries (e.g., epilepsy). Regression analysis indicates a significant positive correlation between disease burden and literature output, suggesting that increasing burden positively influences related publications. Compared with DALYs, the more intuitive metric of deaths has a greater impact on scientific output.

Keywords: scientific research; health needs; disease burden; disability-adjusted life years; neurological diseases

Classification Number: G250; R195.4
DOI: 10.13266/j.issn.0252-3116.2022.10.005

1. Introduction

In modern society, where science and technology constitute the primary productive force, the vigorous development of science is largely driven by societal needs. On one hand, scientific and technological progress permeates all aspects of social development, playing a significant role not only in enhancing productivity and driving societal advancement but also in safeguarding human life and improving well-being. On the other hand, the demand for science and technology from society has become more urgent, as major issues such as disease prevention and treatment and global ecological protection require scientific research to provide viable solutions. The interaction between scientific research and social needs represents a key proposition in the philosophy and sociology of science and has become a focus of research policy worldwide. In 2019, China's National Natural Science Foundation explicitly identified "demand-driven, bottleneck-breaking" research as one of four major categories of scientific questions.

Against the backdrop of deep synergistic development between human society and scientific endeavors, clarifying the interactive relationship between scientific research and social needs holds broad theoretical and practical significance. Previous studies have often adopted philosophical perspectives—such as the social nature of science and the contract between science and society—to explore this relationship at a macro level. These studies consistently demonstrate that science is not a closed, self-sufficient system but rather exists within a broader social environment with which it interacts extensively. While research planning and resource allocation are influenced by multiple factors, prioritizing societal needs and real-world complex problems has become a fundamental consensus. The critical question is: How can we effectively identify the current state and evolution of research in a specific field, employ quantitative indicators to measure social needs, and analyze the alignment and correlation between research and needs? Such investigations can provide valuable references for future research planning and resource allocation, representing an increasingly important concern for science management departments and researchers.

Currently, quantitative exploration of the interaction between science and social needs remains in its infancy, with relevant studies spanning environmental science, agriculture, and medical health fields. Among these, medicine—being most closely related to human welfare—has received relatively extensive attention regarding the relationship between research and health needs. A 2013 editorial in *The Lancet* noted a significant gap between the motivations of most medical research and its original purpose of improving global health, with numerous studies indicating a clear imbalance between research efforts and health needs. Existing research typically uses scientific funding and publications to represent research activity, employing scientometric and statistical methods to explore quantitative relationships with disease burden. Most studies focus on specific diseases and countries, such as chronic respiratory diseases and diabetes in Europe, tropical diseases in Brazil, and cancer in China. Some research also examines the relationship between research and health needs for different disease types at the global level. For instance, Yegros-Yegros et al. constructed search term lists for 134 diseases to explore global imbalances between disease burden and medical research. Overall, existing studies tend to adopt either a global perspective or focus on specific countries/regions, rarely considering the substantial differences in development levels among countries and their impact on scientific capacity. Moreover, most research concentrates on diseases with high burden or mortality, seldom addressing neurological diseases whose health needs are rising with population aging.

In recent years, despite improvements in global health levels, the burden of neurological diseases has increased significantly over the past two decades, becoming a major cause of disability and mortality worldwide. Alzheimer's disease and other dementias have ranked among the top ten causes of death globally since 2019. In China, the average DALYs per thousand people due to neurological diseases increased by over 86% between 2000 and 2015. This high burden has drawn widespread attention, with existing studies conducting bibliometric analyses of research hotspots, treatments, and trends. However, few have examined the quantitative relationship between research and health needs for these diseases. Additionally, most studies on specific diseases or countries use data from a single year or period, rarely investigating long-term, dynamic evolution trends.

Faced with the growing burden of neurological diseases, what is the current state of research? How does it relate to the resulting health needs? These questions require deeper exploration. Building on this literature review, this study uses neurological diseases as a case study, employing over 200,000 publication records from 2000–2019, multiple disease burden indicators for 181 countries, and the Human Development Index. We construct a quantitative analytical framework to explore the alignment, correlation, and regression relationships between neurological disease burden and research output. This study integrates multi-source data and combines scientometrics with regression analysis to provide new perspectives and methods for research on science-society relationships. Practically, it offers empirical foundations for understanding the interaction mechanism between health needs and research in medicine and provides insights for rational research planning and resource optimization.

2. Research Framework and Methods

2.1 Research Framework

Figure 1 [Figure 1: see original paper] presents the analytical framework for quantifying the relationship between scientific research and health needs. The first step involves quantifying both "scientific research" and "health needs." Research output takes various forms, including academic papers, books, conference proceedings, patents, and technical reports. "Research productivity" typically refers to the number of publications by researchers, institutions, or countries over a period. Considering data availability, measurement methods, and comparability, this study uses publication output to represent "research effort" for specific diseases. Health needs is a broad concept generally referring to multi-level (individual, family, societal) requirements for achieving physical, cognitive, emotional, social, and spiritual health. Here, we narrowly define health needs from a "disease" perspective—as the gap between current and desired health states caused by a disease. While previous studies often used single-dimension indicators like incidence, mortality, or disability rates, we primarily employ DALYs, a composite metric of life quantity and quality that measures health loss from premature death and disability. Widely used by WHO and national health statistics, DALYs serve as the main indicator for quantifying health needs in related research.

Research is not the only path to reducing disease burden; improvements in healthcare environments, medical awareness, and resource allocation also play vital roles. For instance, safe vaccines exist for measles, yet over 140,000 people died from it in 2018, mostly in underdeveloped regions. With preventive and therapeutic measures available, reducing measles burden depends more on global vaccine coverage and healthcare improvements. How to quantify the portion of disease burden that requires sustained research and explore its relationship with research output represents an important question. The "research-dependent fraction of global burden of disease" (BoD-RdF) indicator, proposed by Hagenars et al. in 2019, addresses this. It assumes that if a disease's burden varies little across countries, its "research dependence" is high—meaning even advanced healthcare cannot reduce its burden, making research the primary solution. We adopt this indicator to explore the relationship between neurological disease research and health needs.

Additionally, we use the HDI to classify countries by development level. The HDI is a composite statistical indicator proposed by UNDP that evaluates national development from health, education, and economic perspectives (http://hdr.undp.org/en/content/human-development-index-hdi). It classifies countries into four tiers: very high, high, medium, and low development. We use this to explore quantitative relationships between research and health needs across development groups.

From a dimensional perspective, we first conduct basic statistics on global literature output and disease burden for neurological diseases, comparing them with other diseases. Based on HDI classifications, we explore the status and alignment of literature output and disease burden across development levels. Finally, correlation and regression analyses examine quantitative relationships between research and health needs to inform resource allocation. This framework integrates research data with multiple health need indicators using scientometrics and regression analysis, providing a rational and feasible solution for this study and extensible to other regions, diseases, and fields.

2.2 Indicator Quantification and Data Acquisition

2.2.1 Quantification of Scientific Research Academic literature is the primary form of research output and commonly represents research effort for specific fields or diseases. To accurately and comprehensively retrieve literature on six specific neurological diseases, we adopted the MeSH (Medical Subject Headings) search methodology developed by Yegros-Yegros et al. for 134 diseases (including six neurological diseases) in WHO's Global Health Estimates (GHE) project. MeSH, compiled by the U.S. National Library of Medicine, is the most widely used and authoritative thesaurus in medicine. PubMed-indexed literature is professionally indexed with MeSH terms, enabling precise retrieval. We searched PubMed using MeSH terms for six neurological diseases to obtain 2000–2019 Article and Review-type publications (Table 1). Since disease burden and research output have a time lag and previous studies often use 5-year intervals, we matched each burden data year with the subsequent five years of literature (e.g., 2000 burden matched with 2000–2004 publications), yielding four time periods. We also retrieved publication counts for 128 other GHE diseases (2.96 million total) to calculate neurological diseases' share of total disease research.

To ensure accuracy, we excluded MeSH terms containing identical words but referring to different diseases. Since PubMed lacks author affiliation data before 2014 (except for first authors), we used PMIDs to retrieve complete author affiliation data from Web of Science Core Collection for HDI classification. Some publications could be classified under multiple diseases, so the sum of individual disease counts exceeds the total for neurological diseases.

2.2.2 Quantification of Health Needs The disease burden concept was introduced by the World Bank and WHO in 1993. DALYs, as a comprehensive measure of life quantity and quality, have become the primary indicator for quantifying disease burden in WHO and national health statistics. We used DALYs as the main indicator, supplemented by deaths. Data came from WHO's 2016 estimates for 183 countries (2000, 2005, 2010, 2015). Since raw DALYs don't account for population differences, we calculated per-thousand-people DALYs for cross-country comparison. We also adopted the BoD-RdF indicator to explore the portion of burden that could be reduced through enhanced research effort. This global-level indicator is calculated as the first quartile of all countries' per-thousand-people DALYs when sorted ascendingly.

In summary, we primarily use DALYs to represent health needs, supplemented by deaths and BoD-RdF for comprehensive analysis.

2.2.3 Socioeconomic Indicators We obtained HDI data for 2000, 2005, 2010, and 2015 from the UNDP website (http://hdr.undp.org/en/data). Of 183 countries with burden data, 181 (excluding North Korea and Somalia) had HDI data. Table 2 shows the number of countries in each HDI group across periods, revealing an overall upward development trend with decreasing numbers of low- and medium-HDI countries and increasing high- and very-high-HDI countries.

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3. Data Results and Analysis

3.1 Global Perspective

This section first compares the research and burden status of neurological diseases globally using literature data and basic burden indicators (DALYs and deaths). We then analyze the research-dependent disease burden for specific diseases and compare it with literature output.

3.1.1 Comparison of Literature Output and Disease Burden While global health levels have improved, neurological disease DALYs and deaths increased from 2000–2019 (Figure 2 [Figure 2: see original paper]), making them major causes of disability and mortality. Among specific diseases, Alzheimer's disease shows high DALYs and deaths as a common age-related neurodegenerative condition. Epilepsy, characterized by recurrent seizures, also carries high burden and faces social stigma affecting mental health. Migraine, a common condition, shows high DALYs but zero deaths, while Parkinson's disease shows the opposite pattern. Temporally, Parkinson's disease demonstrates the most significant growth in both DALYs and deaths after Alzheimer's disease. Multiple sclerosis has the lowest DALYs but higher publication output than headache disorders. These results suggest some alignment between literature distribution and burden across diseases, with publications correlating more closely with deaths.

From a global perspective, neurological diseases' literature counts, DALYs, and their percentages among all 134 diseases show increasing trends, with literature share consistently exceeding burden share (Figure 4 [Figure 4: see original paper]), indicating adequate research attention. At the disease level (Figure 5 [Figure 5: see original paper]), Alzheimer's disease, Parkinson's disease, epilepsy, and multiple sclerosis show literature shares exceeding DALYs shares across all periods, with parallel temporal trends. However, the two headache disorders show literature shares below their DALYs shares and declining trends, contrasting with their increasing DALYs shares—demonstrating research-health need imbalance. For deaths, literature shares exceed death shares across all diseases, with higher-mortality diseases receiving relatively more attention.

3.1.2 Literature Output and Research-Dependent Disease Burden This section further explores research dependence for each disease and compares it with literature output (Table 3). "BoD-RdF share" refers to a disease's BoD-RdF as a percentage of total BoD-RdF for all 134 diseases. We use "BoD-RdF/DALYs" as an indicator of "research dependence" and "BoD-RdF share/literature share" to measure alignment between research attention and research-dependent burden—values >1 indicate insufficient research, while <1 indicate adequate attention.

The six diseases show substantial differences in research dependence. Headache disorders and epilepsy exhibit higher research dependence than the overall level, indicating small cross-country variation in their burden values. According to BoD-RdF logic, these should receive more research attention, yet headache disorders are clearly under-studied. Alzheimer's disease, Parkinson's disease, and multiple sclerosis show lower research dependence but receive extensive attention.

3.2 Perspective by Development Level

This section examines literature output and disease burden across four HDI groups from "absolute" and "relative" perspectives. "Absolute" refers to each group's global share of neurological disease literature and burden, while "relative" combines each group's data with other diseases to measure comparative levels.

3.2.1 Absolute Level Table 4 shows literature and DALYs shares for each HDI group. Early periods show high burden shares for low-HDI countries, which decline over time as country numbers (and populations) decrease. Medium-HDI countries show fluctuating burden shares due to HDI reclassification of populous nations—China and India accounted for 71.56% of medium-HDI DALYs in 2010. India's shift from low to medium HDI after 2005 and China's move to high HDI after 2015 explain these fluctuations.

In terms of literature output, very-high-HDI countries have long been the primary source of neurological disease publications. Despite growing numbers of very-high-HDI countries (Table 2), their publication share continues declining, indicating increasing research attention from other development levels.

At the disease level (Figure 6 [Figure 6: see original paper]), epilepsy and headache disorders show higher burden shares in low- and medium-HDI countries, while Alzheimer's disease, Parkinson's disease, and multiple sclerosis concentrate in very-high-HDI countries. Publication shares correspond to these patterns, with medium- and low-HDI countries contributing more to epilepsy and headache research.

3.2.2 Relative Level While absolute shares show each group's global contribution, they don't account for population differences or compare against other diseases. We therefore adopt the specialization index (SI) and its normalized form (NSI) to measure relative levels. The formulas are:

$$SI\_Pub_{rd} = \frac{P_{rd}/\sum_d P_{rd}}{P_d/\sum_d P_d} \quad (1)$$

$$SI\_DALY_{rd} = \frac{D_{rd}/\sum_d D_{rd}}{D_d/\sum_d D_d} \quad (2)$$

Normalized to a \$±\$1 range:

$$NSI = \frac{SI - 1}{SI + 1} \quad (3)$$

NSI > 0 indicates above-global-average research effort or burden; NSI < 0 indicates below-average levels.

Figures 7 [Figure 7: see original paper] and 8 [Figure 8: see original paper] show NSI results for DALYs and publications. After controlling for population, neurological disease burden concentrates in very-high-HDI countries, not low-HDI countries. This is particularly evident for Alzheimer's disease (1), Parkinson's disease (2), and multiple sclerosis (4), corresponding to their "low research dependence"—uneven geographic distribution concentrated in high-development countries. However, classifying these three diseases as "low research dependence" seems unreasonable given their increasing burden and lack of curative treatments. This reflects a limitation of the BoD-RdF indicator: it overlooks diseases whose burden concentrates in developed countries.

Epilepsy (3) shows a distinct pattern, with burden more concentrated in low- and medium-HDI countries. Publication patterns show very-high-HDI countries lead neurological disease research, while medium- and low-HDI countries show higher relative attention to epilepsy, matching their burden patterns. Although very-high-HDI countries' absolute publication share is declining, their NSI_{Pubs} shows a slight stable increase, indicating sustained attention to diseases with growing domestic burden.

Overall, neurological disease burden is globally distributed but concentrated in very-high-HDI countries, which are also the main research force. However, very-high-HDI countries pay less attention to diseases with high burdens in lower-HDI countries (e.g., epilepsy).

3.3 Correlation and Regression Analysis

While previous sections analyzed alignment, this section explores relationships between burden and research using correlation and regression.

3.3.1 Correlation Analysis Pearson correlations between three burden indicators (Deaths, Std-DALYs, BoD-RdF) and publications (Pubs) show significant positive correlations between deaths and DALYs with publications (Table 5), confirming that higher-burden diseases receive more research attention. Notably, deaths show a stronger correlation than DALYs, consistent with descriptive statistics. BoD-RdF shows non-significant negative correlation, further demonstrating its limitations as a crude indicator of burden distribution inequality.

3.3.2 Regression Analysis To meet regression assumptions and address heteroscedasticity, we use log-transformed publication counts (LogPubs) as the dependent variable, with Deaths and Std-DALYs as independent variables, controlling for HDI levels. Since BoD-RdF is a global indicator, it's excluded. The model is:

$$logPubs = \beta_0 + \beta_1 StdDALYs + \beta_2 Deaths + \beta_3 HDI\_Low + \beta_4 HDI\_Medium + \beta_5 HDI\_High + \epsilon$$

We created dummy variables for HDI levels (with very-high-HDI as reference). Correlation results (Table 6) show significant linear relationships suitable for regression. Variance inflation factors (VIF) are well below 10, and Durbin-Watson statistics are near 2, indicating no multicollinearity.

Regression results (Table 7) show adjusted $R^2 > 0.6$ across all periods, indicating good model fit. Both burden indicators are significantly positively correlated with publications after controlling for development level, confirming that higher health needs drive greater research attention. Deaths show stronger effects than DALYs in the first three periods, though their impacts converge in the final period, suggesting DALYs are increasingly considered in research planning.

Control variables are all significant, confirming the necessity of controlling for development level. Coefficients for low-, medium-, and high-HDI groups are negative and decrease sequentially, indicating lower publication output relative to very-high-HDI countries. These coefficients increase over time, showing narrowing gaps between development levels.

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4. Conclusions and Discussion

4.1 Research Conclusions

This study constructs a quantitative analytical framework for the research-health needs relationship, using neurological diseases as a case study to examine alignment, correlation, and regression between disease burden and research output across development levels. Key findings:

(1) **Global perspective:** Neurological disease burden increased from 2000–2019, becoming a major cause of disability and mortality. Literature output and its share among 134 diseases also increased, with publication share consistently exceeding DALYs share, indicating adequate research attention. However, some high-burden diseases (e.g., migraine) remain understudied. Research dependence varies substantially across the six diseases—epilepsy and headache disorders show high dependence but low attention, while Alzheimer's disease, Parkinson's disease, and multiple sclerosis show the opposite pattern.

(2) **Development level perspective:** Absolute share analysis shows early high burden in low-HDI countries declining over time, while very-high-HDI countries remain the primary research source. Relative share analysis reveals burden is globally distributed but concentrated in very-high-HDI countries, which are also the main research force—particularly for Alzheimer's disease, Parkinson's disease, and multiple sclerosis. However, very-high-HDI countries show weaker attention to diseases with high burdens in lower-HDI countries (e.g., epilepsy), while lower-HDI countries show relatively higher attention to such diseases. This reflects regional matching between research and burden.

(3) **Correlation and regression:** Multiple burden indicators correlate significantly with literature output, with models explaining >60% of variance. Deaths have greater impact than DALYs, though DALYs are increasingly considered. This suggests that while neurological diseases receive adequate attention, the field should consider composite burden indicators more systematically.

4.2 Implications and Recommendations

Using neurological diseases—a high-burden condition in developed countries—as a case study, we find positive correlations between disease burden and research output, with generally adequate attention but some mismatches for specific diseases. For other disease types, particularly infectious diseases prevalent in less-developed regions, further investigation is needed.

For medicine—a field closely related to human welfare—greater attention should be paid to research-health need alignment. A 2014 *Science* commentary emphasized that integrating multi-source data to analyze research and health needs is crucial for guiding effective resource allocation. While such studies are gaining international attention, they remain exploratory. Chinese science management institutions should strengthen focus on research-society relationships, integrate information science with domain knowledge, link multi-source data, and build domestic medical R&D and health needs monitoring systems to optimize resource allocation and research planning.

Our data show that "death-related" indicators influence research planning more than composite burden metrics. Although deaths are more intuitive, disease costs and social impacts are also heavily influenced by incidence and disability rates. Neurological diseases have relatively low mortality compared to cardiovascular diseases or cancer, but their burden will continue increasing with population aging. As early as 1998, the U.S. Institute of Medicine recommended incorporating disease burden into NIH funding allocation. We suggest that while maintaining attention to neurological diseases, academia should consider composite burden indicators more systematically. Additionally, given the disparity in research capacity across development levels and weaker attention from very-high-HDI countries to diseases burdening lower-HDI countries, global collaboration and rational resource allocation should prioritize diseases causing high burden in lower-HDI countries.

4.3 Limitations and Future Directions

Framework and data: Our analytical framework applies to quantitative research-health need analysis across different data and regions. However, we focused on a single disease category. Future research could expand to comparative analyses across all diseases. Research output encompasses diverse forms beyond publications, including patents and clinical trials. Using only scientific literature limits the scope. Future studies should integrate diverse research data (funding, clinical trials) with disease social contexts and multidimensional social factors to construct more robust statistical models.

Indicators: We adopted the innovative "research-dependent disease burden" concept to reflect burden requiring enhanced research control. However, this indicator appears crude and lacks broad applicability. It overlooks diseases concentrated in developed countries—Alzheimer's disease, Parkinson's disease, and multiple sclerosis are calculated as "low research dependence" despite needing intensive research. Our correlation analysis confirms its limitations in reflecting only burden distribution inequality without considering disease complexity, existing treatments, or research gaps. Future research should combine medical knowledge bases and clinical data to construct multidimensional research-dependent burden indicators.

Research design: While our framework examines burden-research relationships, research priority setting is influenced by multiple factors beyond health needs, including researcher capacity and policy orientation. Our design has limitations in comprehensiveness. Quantitative analysis of research-need dynamics is an important step toward understanding complex science-society interactions. Future studies should incorporate additional influencing factors and social indicators for more comprehensive, systematic investigation of these relationships.

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Author Contributions:

Zhao Wenjing: Conceptualized the framework, collected and processed data, wrote and revised the manuscript.

Zhang Xiaohan: Conducted literature review, processed and validated data, revised and reviewed the manuscript.

Zhang Lin: Proposed the research topic, designed the study, supervised data processing, revised and finalized the manuscript.

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