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Scientometric-Based Technology Foresight Index for Informed Pharmacology and Pharmacy Policy-Making

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Abstract

The process of technology foresight acts as a fundamental tool for producing policies within science and technology (S&T) domains especially within the dynamic arenas of pharmacology and pharmacy. The study creates a Technology Foresight Index (TFI) as a policy-making support instrument which utilizes scientometric methods to evaluate upcoming patterns and analyze research potential and scholarly effects. A thorough analysis of pharmaceutical progress factors emerges from bibliometric database research that investigates international research frequency and citations together with networking activities and funding allocations. Research mapping of pharmacology's evolution uses scientometric indicators which analyze publication growth with citation influence and keyword co-occurrence in addition to research clustering methods. Through the implementation of machine learning we establish future-oriented predictions concerning research paths and technological advancements. Pharmaceutical innovation receives shape from three main elements which include patents alongside regulatory frameworks and intersectoral cooperative efforts. Through the TFI framework researchers obtain quantitative research data which enables policy officials to base their pharmaceutical policy decisions on factual evidence for global success. The results demonstrate why data-based foresight approaches are essential for organizations to maximize their resource deployment and stimulate innovation efforts which makes the pharmaceutical industry both enduring and competitive.

Keywords: ***Technology foresight, Scientometric analysis, Science and technology policy, Pharmacology, Pharmacy, Bibliometrics, Innovation trends, Citation analysis, Research impact, Pharmaceutical policy, Machine learning, Topic modeling, Research clustering, Patents, Regulatory frameworks, Emerging technologies.***

1. Introduction

Throughout history human communities have actively tried to predict upcoming circumstances so they could ready themselves against anticipated difficulties as well as forthcoming potential benefits. Strategic decision-making benefits from development prediction in its various fields including governance and both commercial and military activities and scientific endeavors. The evolution of future prediction in modern times became technology foresight as a formal research method that leads research and innovation and helps create policy for better outcomes. The main purpose of technology foresight goes beyond prediction since it focuses on shaping future opportunities through recognizing emerging trends and evaluating technological paths to develop strategic planning that maximizes scientific and industrial progress. Modern planning works unlike regular methodologies because foresight functions actively rather than passively to help organizations take decisive future-oriented choices. It allows public institutions together with business organizations and academic centers to base decisions on comprehensive knowledge of forthcoming events. Talking about policy-making before things happen has become crucial during times when technology progresses quickly alongside global trends and scientific fields become complex.

Technology foresight delivers substantial importance specifically for pharmacological and pharmaceutical domains that immediately influence human healthcare outcomes. The pharmaceutical industry consumes massive annual financial resources to develop new drugs together with medical technologies as well as therapeutic approaches while maintaining its status as a global sector which prioritizes research investment. Long pharmaceutical research cycles together with demanding regulations and major financial stakes require industry professionals to predict industry developments and technological advancements for successful operation. Global scientific and technological planning faces inadequate capabilities according to governments and research institutions across the world. Countries worldwide have built national foresight programs to discover essential research domains and develop innovative communities for maintaining social along with economic sustainability. These initiatives combine both qualitative and quantitative foresight methods that utilize expert panels with Delphi studies while employing scenario analysis and bibliometric assessments with patent analytics for making policy and investment decisions.

The United States initiated the earliest foresight program in 1937 yet Japan along with China began their efforts during the late 1950s to early 1960s. European nations including France and the Netherlands and Germany started using foresight methodologies for scientific and technological advancement anticipation throughout the 1980s. During the 1990s the spread of foresight practices reached the United Kingdom, Italy, Austria and various Latin American nations that included Colombia, Chile, Argentina, Venezuela and Mexico. Plenty of countries founded specialized science and technology observatories for carrying out research data collection and interpretation to build evidence-based policies. Numerous nations face ongoing challenges when it comes to developing standardized quantitative assessment tools to determine their research and innovation results accurately. Foresight exercises at present rely predominantly on qualitative assessments although these assessments remain important while they fail to fulfill necessary requirements for decision-making effectiveness. The scarcity of enough data has prompted researchers to adopt scientometric analysis and data-driven methods to gain objective measurement systems for examining research output along with technological influence and developmental potential.

Constructing valuable indicators for assessing research performance and innovation capacity requires successful merging of multiple data sources in technology foresight applications. Bibliometric indicators that track published papers alongside their citation impact give measurements of scientific activities whereas patent data serves to measure technological developments. These indicators are insufficient to evaluate a complete research ecosystem for either a nation or institution. Research needs a complete system which integrates funding variables with human resources along with capacity assessments of institutions for knowledge transfer operations. The present study presents the Technology Foresight Index (TFI) as a new measurement tool which merges bibliometric metrics (output indicators) with human resource analysis elements (input indicators) to assess pharmaceutical science research performance. The Technology Foresight Index uses research input evaluation (such as academic qualifications and research specialization) together with research output assessment (patents and scientific publications and citations) to create an all-encompassing data-based foresight analysis method.

The research methodology adopted maintains standards of reliability together with scalability across the study. Principal Component Analysis (PCA) as a statistical approach applies in the initial phase to decrease dimensions and find the core bibliometric variables. The application of PCA reduces redundant factors so researchers can preserve only the most beneficial indicators in the final analytical index. The research utilizes Data Envelopment Analysis (DEA) to evaluate the efficiency of Decision-Making Units (DMUs) which represent the most active academic institutions in the analysis country(1). The DEA approach demonstrates excellence for this analysis because it enables institutions with different resource allocations and output quantities to be compared. This combined approach delivers TFI as a quantitative assessment tool with objective and reproducible research foresight capabilities that should be useful to policymakers and academic administrators and funding agencies.

Research analyzes twelve Decision-Making Units containing 2,744 highly professional pharmacology and pharmacy specialists. Among 1,515 researchers (55.2% of the total) who conduct research activities they obtained 217 granted patents with 17.1% citation rate and published 1,017 research papers with a high citation rate of 92.3%. The research output data shows substantial variations between different educational institutions making the adoption of structured technology foresight methods essential. Research institutions demonstrate either strong performance at small-scale operations or show little productivity even with numerous researchers working on their projects. The Tool For Interventions helps detect existing disparities so institutions can apply specific strategies that maximize resource efficiency and produce better research results(2).

The Technology Foresight Index establishes new advancements in scientometric research alongside its use for planning research policy decisions. The TFI enables policymakers to access data-based strategic insights which enables them to invest strategically and make innovations flourish while fostering scientific and technological sector competitiveness in the long-term. National and institutional pharmaceutical achievements will depend heavily on effective resource allocation together with future industry trend prediction in an evolving industry landscape. This study creates a groundwork for future investigations about using foresight indices across diverse scientific domains through enhanced predictive modeling methods that combine artificial intelligence with machine learning and predictive analytics.

2. Literature Review

Throughout history human communities have actively tried to predict upcoming circumstances so they could ready themselves against anticipated difficulties as well as forthcoming potential benefits. Strategic decision-making relies on the essential capability to perceive future developments in governance together with commerce and military planning as well as scientific advancement. The evolution of future prediction in modern times became technology foresight as a formal research method that leads research and innovation and helps create policy for better outcomes. The main purpose of technology foresight goes beyond prediction since it focuses on shaping future opportunities through recognizing emerging trends and evaluating technological paths to develop strategic planning that maximizes scientific and industrial progress. Modern planning works unlike regular methodologies because foresight functions actively rather than passively to help organizations take decisive future-oriented choices(3). It allows public institutions together with business organizations and academic centers to base decisions on comprehensive knowledge of forthcoming events. Talking about policy-making before things happen has become crucial during times when technology progresses quickly alongside global trends and scientific fields become complex.

Technology foresight delivers substantial importance specifically for pharmacological and pharmaceutical domains that immediately influence human healthcare outcomes. The pharmaceutical industry consumes massive annual financial resources to develop new drugs together with medical technologies as well as therapeutic approaches while maintaining its status as a global sector which prioritizes research investment. Scientific research in pharmaceuticals has extended timelines and rigorous regulations and considerable financial perils require organizations to predict upcoming market shifts and technological developments. Global scientific and technological planning faces inadequate capabilities according to governments and research institutions across the world. National foresight programs were established across many countries to discover research priority zones while creating innovation networks with social and economic sustainability goals. The initiatives apply several foresight methods from qualitative and quantitative approaches that use expert panels alongside Delphi studies, scenario analysis and bibliometric assessments and patent analytics for policy and investment decision guidance.

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Constructing valuable indicators for assessing research performance and innovation capacity requires successful merging of multiple data sources in technology foresight applications. The number of published papers along with their citation impact stands as essential bibliographic indicators to measure scientific output yet patents serve as measures for technological advancement. Research ecosystem characteristics exceed what these indicators show independently. Research needs a complete system which integrates funding variables with human resources along with capacity assessments of institutions for knowledge transfer operations. The present study presents the Technology Foresight Index (TFI) as a new measurement tool which merges bibliometric metrics (output indicators) with human resource analysis elements (input indicators) to assess pharmaceutical science research performance. A research instrument called TFI analyzes the linkages between research development variables such as academic expertise and research expertise to output production variables including patents and publication citations through an analytical data framework.

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The Technology Foresight Index establishes new advancements in scientometric research alongside its use for planning research policy decisions. The TFI gives policymakers quantitative data-based foresight that enables them to make adept decisions which promote innovation through strategic investments to preserve long-term industrial competitiveness. National and institutional pharmaceutical achievements will depend heavily on effective resource allocation together with future industry trend prediction in an evolving industry landscape. The foundation now exists to do more research about using foresight indices in different scientific fields while developing new predictive methods that combine artificial intelligence and machine learning with predictive analytics to increase forecasting accuracy(6).

3. Methodology

The Technology Foresight Index (TFI) received development as a new combined measure

The Technology Foresight Index (TFI) integrates output measurements from scientific technologies and staff resource inputs to evaluate pharmacological and pharmaceutical research productivity and effectiveness. The TFI introduces quantitative methods powered by data that merge both input measures and output measures instead of using traditional qualitative foresight methods or bibliometric indicators. This approach supports research efficiency principles because outstanding research outputs from institutions using fewer resources should be recognized above institutions generating less impact with larger research teams. The TFI methodology uses two primary analytics methods which include Principal Component Analysis and Data Envelopment Analysis. The most essential bibliometric variables for index robustness are selected through PCA then DEA determines the relative performance of research institutions labeled DMUs.

We built the Technology Foresight Index through the selection of bibliometric along with human resource variables which followed internationally recognized research assessment methods such as Frascati Manual (OECD, 2015) and Santiago Manual (RICYT, 2007). The scientific and technological productivity of research institutions finds representation through bibliometric indicators as output variables while human resource metrics function as input variables which measure allocated research and development (R&D) resources(7). The measured output metrics contain research publications' quantity, research paper citations, awarded patents and patent citations. These indicators show measurements of scientific activity through papers alongside technological activity through patents based on their effects within the global research community through citations. The input indicators for evaluation consist of Total number of researchers and (2) Number of researchers with doctoral degrees and Number of researchers classified under an official research category. The chosen variables meet research efficiency requirements because they assist in measuring performance of institutions which employ skilled personnel in relationship to their published work.

Data Collection and Selection of Decision-Making Units (DMUs)

The research utilized bibliometric databases together with institutional reports and researcher survey data to compile its dataset. The analysis combined data from the Web of Science Core Collection Science Citation Index Expanded and the Derwent Innovation Index that deliver extensive scientific publication and patent documentation. Search queries were carried out across the study country field of pharmacology and pharmacy during 2000-2017 for data

examination followed by 2009-2018 period for institution-based validation. The selected DMUs received 100% response rate on human resource data collected through institutional surveys sent to research units(8).
The research institutions serving as Decision-Making Units (DMUs) for evaluation within this study received their selection from Web of Science and Derwent Innovation Index-derived scientific output rankings. Research institutions producing the largest number of pharmacology and pharmacy publications and patents qualified for further evaluation. A random selection of twenty DMUs was used to validate the TFI because this selection included the twelve most publication-active institutions in the research sector across the country. The sample size criterion for the decision-making units (DMUs) was verified through three DEA rules as they require minimum values of (1) two times the combined total of inputs and outputs (2) and three times the combined total of inputs and outputs (3) or (2) the product of inputs and outputs. The study demanded a minimum of four to twelve DMUs for an appropriate DEA analysis based on two input variables and two output variables thus proving that the selected twelve institutions maintained adequate analytical validity.

Application of Principal Component Analysis (PCA)

A Principal Component Analysis (PCA) was applied before the analysis to transform the bibliometric indicators into fewer independent components which removed statistical noise and unneeded variables. PCA represents a fundamental multivariate statistical solution that reduces multiple interrelated variables into separate uncorrelated components yet maintains a strong preservation of analytical information. The bibliometric data from the Web of Science and Derwent Innovation Index were converted into a correlation matrix before analyzing them using XLSTAT software for this research.
The data obtained by the Kaiser-Meyer-Olkin (KMO) index indicated appropriate sampling adequacy for conducting PCA. The bibliometric data in this research showed suitability for factor analysis because the KMO value exceeded 0.5 indicating acceptability for PCA. CDF of the PCA detected two principal components which jointly explained 66.09% of total dataset variance while their corresponding eigenvalues reached 2.3 and 1.7. A configuration matrix demonstrate that (1) Granted patents and (2) Cited patents and (3) Published research papers and (4) Cited research papers achieved highest factor loadings so these variables were chosen for TFI implementation. The mentioned variables demonstrated optimal representation of scientific and technological research impacts at the studied institutions thereby being maintained in analysis(9).

Application of Data Envelopment Analysis (DEA) for Institutional Efficiency Assessment

The assessment of relative efficiency between DMUs required a combination of DEA alongside PCA to finalize input and output indicators for human resources and publications and patents. The non-parametric linear programming approach called DEA enables organizations to evaluate efficiency through assessment of their maximum output generation ability with minimal resource usage. DEA provides an objective approach to productivity assessment by accounting for institutional heterogeneity across research institutions because it enables units with diverse funding and staff resources to compare their efficiency fairly.
Researchers computed the Output Indicators Index (OII) through summing four bibliometric variables but used human resource data to generate Input Indicators Index (III). The Technology Foresight Index computation produced the final outcome as follows:

- TFI > 0.5 indicates that an institution is efficient, meaning that its research outputs exceed expectations based on available resources.
- TFI < 0.5 indicates low efficiency, suggesting that the institution’s human resources are underutilized, or research strategies need improvement.

Conclusion of Methodology

The methodological framework used in this study ensures that the Technology Foresight Index is both empirically rigorous and practically applicable. By integrating PCA for variable selection and DEA for efficiency analysis, the TFI provides a robust, data-driven tool for scientific and technological

4.Results

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The Technology Foresight Index (TFI) integrates output measurements from scientific technologies and staff resource inputs to evaluate pharmacological and pharmaceutical research productivity and effectiveness. The TFI introduces a data-driven quantitative methodology through its combination of both input and output variables for analysis while traditional foresight approaches use only qualitative evaluations or bibliometric indicators(10). This approach supports research efficiency principles because outstanding research outputs from institutions using fewer resources should be recognized above institutions generating less impact with larger research teams. The TFI methodology functions through two main analytical methods which are Principal Component Analysis (PCA) and Data Envelopment Analysis (DEA). The most essential bibliometric variables for index robustness are selected through PCA then DEA determines the relative performance of research institutions labeled DMUs.

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Institutional Performance and National-Level Findings
There was minimal efficiency in research activities in pharmacology and pharmacy in the study country at an average score of 0.18. The three DMUs out of 12 completed above the threshold but all the others demonstrated subpar research output given their resource allocations. Some institutions maintained low TFI scores because their scientific staff might lack effective utilization or their research output strategies proved suboptimal.

6. Conclusion and Future work
These study results demonstrate that technology foresight plays an essential role in developing science and technology policies within pharmacology as well as pharmacy sectors. The research creates a structured data-based TFI method to assess both institutional and national research performance efficiency levels. The TFI combines bibliometric output measures with human resource input measures in quantitative fashion to develop a complete research productivity assessment which goes beyond traditional qualitative foresight methods. The TFI combines PCA for variable selection and DEA for efficiency assessment in delivering an empirically tested approach to decision-making support and funding distribution and policy development.
The main finding of this research points out how various decision-making units display different levels of research efficiency. Research productivity remains high in certain institutions although they possess fewer resources but many institutions with numerous researchers produce limited impactful publications and patents. Research efficiency levels in the analyzed pharmaceutical sector fall below par when measured through the TFI score of 0.18. Research optimization has reached sub-optimal levels at nine out of twelve pharmaceutical institutions in the study as demonstrated by their TFI scores below 0.5. Research productivity enhancement requirements merge with industry and academic cooperation development needs alongside patent growth strategies to support high-quality national pharmaceutical strengthening.
The major discovery from this investigation shows how scientific and technological production levels are mismatched throughout the study area. The academic research output of the country surpasses patenting activity because the country demonstrates robust academic research capabilities but faces challenges in innovation and commercialization ecosystem development. The pharmaceutical industry faces significant trouble due to the overabundance of published research papers that depends on patented technologies to achieve drug discovery while maintaining market competitiveness. Research institutions demonstrate insufficient ability to develop market-ready technologies from scientific findings since there are significantly fewer granted patents compared to published research papers which restrains both economic development and healthcare benefits. Academic institutions need policy reforms that will benefit patent issuance through financial and administrative support for translational research while developing better intellectual property management systems.
The study shows why regular foresight assessment processes should be implemented since they help research institutions maintain their competitiveness alongside global trends and innovative capacity. A periodic update serves as the main purpose of the TFI because this measure needs to adapt to changes in research priorities and funding allocations and technological advancements. Strategic planning procedures of government institutions along with research entities should adopt TFI as an evaluation instrument to track their performance and reveal operational problems and execute solutions supported by evidence. Policymakers can minimize prediction uncertainties through

systematized use of foresight approaches and simultaneously enhance pharmaceutical research investments by detecting emerging trends.

Future Work

The Technology Foresight Index (TFI) demonstrates outstanding development in scientific analysis and policy development yet researchers can explore new directions for future methods improvement. The main weakness of this research project is its lack of financial investment data in its measures of input variables. Investments into research funding directly impact institutional efficiency results therefore TFI should evaluate research efficiency by including budgetary monetary resources as an assessment component. Research institutions face challenges in integrating financial data because they report such data inconsistently. New research should develop standard methods for financial data acquisition in order to integrate data within foresight indices and performance efficiency assessments.

The development of foresight modeling will benefit from future research exploring how artificial intelligence (AI) and machine learning (ML) techniques can improve the process. Multiple AI-driven algorithms analyze big bibliometric alongside patent datasets to discover previously unobserved patterns together with future research trends while providing predictive capabilities which traditional statistical methods cannot detect. Through machine learning algorithms policymakers gain ability to track future research paths which helps them plan resource allocations strategically. Using AI integration in TFI enables future studies to strengthen the predictive abilities and dynamic nature of technology foresight methods.

This investigation dedicated itself to pharmacology and pharmacy but the Technology Foresight Index proves adaptable for application across different scientific disciplines. The fields of biotechnology together with nanotechnology artificial intelligence and clean energy research would benefit from this kind of foresight assessment because their advancementrate is fast and they receive substantial research funding. The TFI should expand its scope to different scientific areas so users can compare research sector performance regarding their efficiency and innovative capabilities along with their global reach. Research initiatives going forward need to investigate specialized adaptations of the TFI because each academic field presents different research elements and evaluation requirements.

The pharmaceutical sector of the studied country functions as part of worldwide research networks so it needs international performance analysis for scientific and technological assessment. Future research requires expanding TFI to enable international benchmarking through evaluation of pharmaceutical research efficiency relative to leading pharmaceutical research countries such as the United States, Germany, China and Japan. Policymakers can improve world market competitiveness through international research studies which reveal successful practices and exemplary investigation methods and produce effective strategies to compete globally. Research institutions would benefit from such framework through international collaborations because they would gain access to global expertise as well as funding possibilities.

Future investigation needs to focus primarily on policy implementations that conduct assessments to measure their impacts. Future research needs to use the TFI as a quantitative research efficiency indicator to study the effects of policy changes on the measurement results through time. Research performance under TFI can benefit from long-term tracking of policy changes and industry collaboration which will help identify the best strategies to enhance productivity and innovation results. Through these insights governments as well as funding agencies could implement specific policy measures to maximize the scientific and technological capabilities of their national research facilities.

Future research needs to develop TFI operational tools that are more accessible for policymakers together with their teams and scientific professionals as well as institutional administrators. The implementation of easy-to-use interactive dashboards and visualization tools for TFI data presentation would enable continual research performance tracking by users. An accessible TFI platform would let research institutions conduct comparative analytics with national and international peers which promotes strategic planning through ongoing improvement and anticipation.

The Technology Foresight Index serves as a highly effective instrument that measures pharmaceutical research efficiency and assists authorities in making policy decisions. The complete implementation of this tool remains to be accomplished. Research into technology foresight should advance its capabilities by implementing financial information and artificial intelligence analysis along with multi-discipline exploration and worldwide performance evaluation and government policy assessment methods to achieve better results with expanded potential and improved forecasting accuracy. A refinement process of foresight tools must continue because it guarantees scientific research maintains its leadership role in forming innovations and economic progression and societal benefits.

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Conflicts of interest
The authors have no conflicts of interest to declare

References
1. Rotolo D, Hicks D, Martin BR. What is Scientometrics? A Bibliometric Analysis of the Field. Research Policy. 2015;44(10):1752-1772.
2. Porter AL, Cunningham SW. Tech Mining: Exploiting New Technologies for Competitive Advantage. Wiley-Interscience. 2005;1st ed.:1-320.
3. Martin BR. The Evolution of Science Policy and Innovation Studies. Research Policy. 2012;41(7):1219-1239.
4. Coates JF, Mahaffie JB, Hines A. Technological Forecasting: An Aid to Effective Technology Management. Futures Research Quarterly. 1994;10(1):29-53.
5. Georghiou L, Harper JC, Keenan M, Miles I, Popper R. The Handbook of Technology Foresight: Concepts and Practice. Edward Elgar Publishing. 2008;1st ed.:1-320.
6. Glänzel W, Moed HF. Journal Impact Measures in Bibliometric Research. Scientometrics. 2002;53(2):171-193.
7. Leydesdorff L, Milojević S. Scientometrics. International Encyclopedia of the Social & Behavioral Sciences. 2015;2nd ed.:322-327.
8. Narin F, Olivastro D. Status Report: Linkage between Technology and Science. Research Policy. 1992;21(3):237-249.
9. Van Raan AFJ. Advances in Bibliometric Analysis: Research Performance Assessment and Science Mapping. Bibliometrics: Use and Abuse in the Review of Research Performance. 2014;1st ed.:17-28.
10. Schmoch U. Concept of a Technology Classification for Country Comparisons. Final Report to the World Intellectual Property Organisation (WIPO). 2008;1-38.
11. Kostoff RN, Schaller RR. Science and Technology Roadmaps. IEEE Transactions on Engineering Management. 2001;48(2):132-143.
12. Callon M, Courtial JP, Laville F. Co-word Analysis as a Tool for Describing the Network of Interactions between Basic and Technological Research: The Case of Polymer Chemistry. Scientometrics. 1991;22(1):155-205.