Development and Prospects of Policy Informatics: Postprint

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Abstract

[目的/意义] To systematically review and summarize the theoretical framework and development path of policy informatics, in order to consolidate the theoretical and methodological foundations for policy science, bibliometrics, and other related research. [方法/过程] Grounded in domain informatics, this study clarifies the developmental origins and conceptual connotations of policy informatics, provides a detailed synthesis of its research content and research process, proposes a mutually reinforcing disciplinary system centered on four aspects of "theoretical foundation—methodology and technology—application practice—education management" , and constructs a research system for policy informatics from the two dimensions of theoretical foundation construction and knowledge landscape depiction. [结果/结论] Policy informatics primarily focuses on massive multi-source heterogeneous data, utilizing methods such as bibliometric analysis, social network analysis, content analysis, text mining, and visualization to conduct research on policy change processes and evolutionary patterns, policy quantitative analysis and effectiveness evaluation, intergovernmental policy relations and policy gaming, and the relationship between policy research and scientific research. Future efforts need to build specialized domain-specific policy big databases, develop dedicated policy analysis techniques and tools, conduct extensive and in-depth case studies, and form a high-quality academic community.

Full Text

Preamble

Abstract: [Purpose/Significance] This paper systematically reviews and summarizes the theoretical framework and development path of policy informatics, aiming to lay a solid theoretical and methodological foundation for related research in policy science, bibliometrics, and other fields. [Method/Process] Relying on subject informatics, this study clarifies the origin and conceptual

connotation of policy informatics, comprehensively summarizes its research content and process, proposes a disciplinary system centered on four mutually reinforcing aspects— "theoretical foundation, methodological techniques, application practice, and education management" —and constructs a research system for policy informatics from the perspectives of theoretical foundation building and knowledge mapping. [Result/Conclusion] Policy informatics primarily focuses on massive multi-source heterogeneous data, utilizing methods such as bibliometric analysis, social network analysis, content analysis, text mining, and visualization to investigate policy change processes and evolutionary patterns, conduct policy quantitative analysis and effectiveness evaluation, examine intergovernmental relations and policy games, and explore the relationship between policy research and scientific research. Future development requires building specialized domain-specific policy databases, developing dedicated policy analysis techniques and tools, conducting extensive and in-depth case studies, and forming high-quality academic communities.

Keywords: policy informatics; policy quantification; policy metrics; interdisciplinary; subject informatics

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The advancement of big data and information technology has profoundly impacted contemporary social development. Turing Award winner Jim Gray proposed that science has entered a fourth paradigm—data-intensive scientific discovery. As data in various disciplines grow rapidly and accumulate, numerous fields have intersected and integrated with information science, forming new research areas and presenting a "dualistic" development trend: "Computational-X" and "X-informatics"[1], where X represents specific disciplines such as biology or chemistry. Building on existing "X-informatics" research, Zhang Zhiqiang and colleagues summarized and proposed a unified concept— "subject informatics" —which they define as an interdisciplinary field that uses information science and computational science techniques, methods, and tools to collect, store, process, analyze, and visualize scientific data for knowledge discovery and strategic decision-making consultation [2]. In their book *Subject Informatics and Subject Knowledge Discovery*, they meticulously explored the data discovery processes and knowledge organization methods of biomedical informatics as a representative field of specialized informatics, noting that specialized informatics exhibits both clear disciplinary dependence and general characteristics of subject informatics [3]. Policy informatics represents the concrete manifestation of subject informatics in the domain of policy science, emerging as a new direction in response to the impact of data and information technology on the policy process, the rise of open data and open government, and the research dilemmas of traditional policy analysis. To some extent, it inherits the theoretical foundation and knowledge framework of subject informatics.

Currently, the concept of policy informatics has not yet been widely dissem-

inated, but related research is flourishing. Scholars in public administration focus on the policy lifecycle, particularly policy processes and formulation, attempting to use cutting-edge technologies such as machine learning, big data, and knowledge graphs to provide analytical services for policy processes and support evidence-based government decision-making, with evidence-based policymaking at its core [4-6]. The library and information science community primarily employs bibliometric methods to analyze the content and structural attributes of policy texts, aiming to reveal the evolutionary patterns of policies in specific fields, themes, or periods, grasp policy objectives and intentions, reveal policy tool combinations, and evaluate policy implementation performance. This has led to the formation of a unique research branch—policy metrics—including policy document metrics, policy science metrics, and policy altmetrics [7-9]. Political scientists, using social media data as their object of study, aim to examine policy preferences, political opinions, and political positions [10-11]. In recent years, with the surge of various policy information data, continuous updates in data processing methods, and increasingly sophisticated data analysis platforms, interdisciplinary integration has deepened, and research boundaries between different fields have become increasingly blurred, which underscores the significance of proposing the concept of policy informatics. In 2020, the 260th Shuangqing Forum organized by China' s National Natural Science Foundation was successfully held in Beijing, with the theme "Policy Informatics and Policy Intelligence" [12]. The forum recognized policy informatics and policy intelligence as international frontier interdisciplinary fields, indicating that China is increasingly aware of the importance of policy informatics and that this field holds great potential for future development. However, as a new direction at the intersection of policy science and big data analysis technology, systematic research on policy informatics remains limited, and a unified and clear definition and connotation are still under development. Therefore, the urgent priority for developing policy informatics is to consolidate its theoretical foundation and delineate its knowledge landscape.

The authors argue that policy informatics should be a comprehensive research field that integrates the characteristics of policy process information analysis from public management, the quantitative policy information research features from library and information science, and other related fields for big data analysis of policy information, analysis of policy process patterns, and policy decision-making consultation.

This study uses Web of Science and CNKI as data sources, constructing search queries TS=(Policy Informatics OR PoliInformatics OR Policy Quantification) and Subject=(policy informatics OR policy metrics OR policy document metrics OR policy science metrics OR policy quantification), while separately examining key journals in policy science. After manually screening relevant literature based on citation frequency and disciplinary fields, and conducting backward searches for valuable references, the study strives to ensure both recall and precision. Based on in-depth reading and reflection, the paper first reviews the background and development history of policy informatics, clarifies related concepts, and

defines its connotation. Second, it summarizes the research content and process of policy informatics and attempts to construct its disciplinary system. Finally, it discusses future development directions based on the current state of policy informatics research.

2. Theoretical Foundations of Policy Informatics

2.1 Background

In the era of big data, policy data is growing rapidly, and numerous critical issues have emerged in policy research. For example, how can we scientifically and reasonably use relevant tools and methods to quantify policy documents and provide robust evidence for policy formulation? How can we extract knowledge from massive policy information to evaluate decision outcomes or conduct forward-looking predictive research? How can we engage more stakeholders and foster positive interactions to optimize policy processes while fully respecting their wishes? Consequently, policy informatics has emerged as a problem-oriented field driven by changes in the external environment of policy analysis and the demands arising from policy analysis dilemmas (see Figure 1 [Figure 1: see original paper]).

2.1.1 Changes in the Policy Analysis Environment Any paradigm shift in research is accompanied by changes in the research environment. The explosive growth of various types of data and the rapid development of information, computing, and communication technologies have provided a solid data foundation for policy quantitative analysis research. This is mainly manifested in three aspects: First, the rise of open data and open government movements, along with the vigorous development of new media, has provided substantial available data for policy analysis. Second, the rapid advancement of emerging information technologies offers new solutions for complex computation of policy data and deep mining of policy patterns. Third, conceptual models and visualization technologies enhance the ability to understand complex information and communicate it to different audiences. Simultaneously, driven by the needs of policy research, interdisciplinary integration, penetration, and cross-fertilization have intensified. Scholars with backgrounds in information science, mathematics, computer science, and other disciplines have devoted themselves to policy analysis research, bringing different policy analysis methods and perspectives. These changes in the talent environment have greatly expanded the research boundaries of traditional policy analysis and enhanced the influence of policy quantitative research.

2.1.2 Dilemmas in Policy Analysis Research In the 1950s, Harold Lasswell first proposed the concept of policy science based on the vision of constructing a "scientific study of policy."Subsequently, policy science experienced various developmental stages, including the Lasswell-Dror era and the post-Lasswell era [14]. Traditional policy analysis begins with the interpretation of policy docu-

ments, which is a subjective and qualitative process. Given the complexity of policy issues, policymakers often rely on intuition, personal experience, small-scale interviews, public opinion polls, or news media analysis, and the validity of these approaches is frequently questioned [15]. Policy quantitative research can provide a beneficial supplement. In fact, the government' s use of data for policy analysis to provide reference for decision-making has long been applied in policy activities. In the early 20th century, President Roosevelt realized how little was known about how the U.S. economy worked, leading to the development of the national income accounting system by K. Simon of Harvard University and S. Richard of Cambridge University, which provided a data foundation for measuring and evaluating the overall performance of the economy [16]. As evidence-based policymaking has become increasingly important, traditional qualitative, small-sample, and random policy science research has faced challenges.

2.2 Development Characteristics of Policy Informatics at Home and Abroad

With the development of science and technology, the field of public policy abroad has begun to use information and technology more intensively and creatively to improve decision-making processes and policy formulation, particularly under complex conditions. There is a greater tendency to use modeling and simulation [17], system dynamics [18], network analysis, data mining, and data visualization to explain policy process phenomena and serve policy decision-making, achieving information-rich policy decision support. In 2007, Arizona State University established the Center for Policy Informatics [19]. In 2008, two scholars from the university' s School of Public Affairs, Y. Kim and E. W. Johnston, proposed the concept of Policy Informatics v1.0 [20], aiming to actively seek the participation of multiple stakeholders and harness the potential of modern information technology to advance scientific policy formulation. In 2010, the Center for Policy Informatics hosted a symposium on policy informatics themed "Innovation in Policy Science under Informatics," with 25 scholars from 10 U.S. universities participating. Ultimately, eight academic outcomes related to policy informatics were published in a special issue of *The Innovation Journal* in January 2011 [21]. These studies [22-29] brought new hope for conducting policy research with advanced information, computing, and communication technologies and are regarded as the earliest attempts at policy informatics research. In 2012, the University at Albany, SUNY, began building the Policy Informatics Network to use information and computation to find effective ways to understand and solve complex social problems [30]. In 2013, the U.S. National Science Foundation (NSF) funded a policy informatics project at the University of Washington, encouraging scholars from different disciplines such as computer science, information science, electrical engineering, and statistics to collaborate on policy informatics research [31]. In 2014, the Center for Technology in Government at Albany hosted a workshop on integrating data-intensive analytical skills in public affairs education, representing the convergence of two streams of research activities on policy informatics and policy modeling developed in the U.S. and

Europe over the previous few years [32]. In 2015, E. W. Johnston et al. [33] published the first monograph on policy informatics, *Governance in the Information Era: Theory and Practice of Policy Informatics*, which systematically analyzed and summarized policy informatics from theoretical and practical perspectives and envisioned its future development directions. In 2016, J. Höchtl et al. [34] proposed the concept of "e-policymaking," aiming to provide convincing analysis to identify and describe new analytical methods that can support public policy problem-solving and decision-making processes while considering the public' s demand for transparency and participation. This concept constitutes an important component of policy informatics.

Domestically, the term "policy informatics" appeared relatively late. Zhang Nan first used the concept in a 2015 article titled "Public-Derived Big Data Analysis and Reconstruction of Government Decision-Making Processes" [35]. However, the term has not been widely adopted. Domestic scholars' analysis based on policy data has primarily focused on mining and quantitative analysis of policy text information, representing a post-hoc exploration and revelation of policy patterns. In 2015, Huang Cui et al. proposed a new direction for public policy research, using the term "policy document quantification" to refer to the analysis of policy texts' content and external attribute features, aiming to reveal the selection and application of policy tools, the distribution of interests and game processes in policy processes, and the internal logic and historical patterns of policy evolution [36]. Li Jiang and colleagues applied bibliometric methods based on the three major laws— "Lotka' s Law," "Bradford' s Law," and "Zipf' s Law" —to policy science research, formally proposing the concept of "policiometrics" [37]. In 2017, Ding Jielan et al. applied scientometric methods to science and technology policy research, exploring the application status of scientometrics in policy science [38]. Subsequently, the concept of metrics continued to deepen. The concept of "Five Metrics" formally emerged as a topic at the 16th International Conference on Scientometrics and Informetrics (ISSI) in 2017 [39], mainly including bibliometrics, scientometrics, informetrics, webometrics, and knowledgometrics, all of which focus on the quantitative study of information, particularly textual data and often unstructured text data. Consequently, the unit of analysis in metrics has shifted from document data to more granular knowledge units, gradually penetrating the field of policy science and extending the concept of policy metrics [40]. Additionally, scholars have conducted specialized research on policy documents in references based on altmetrics, proposing policy document altmetrics indicators [41-43]. Such research typically relies on policy data from the Altmetric.com platform, evaluating the social value and utility of academic achievements through citations or mentions in policy documents.

Overall, policy informatics abroad is more of a methodology, referring to research that uses quantitative methods such as big data, network analysis, and visualization to improve decision-making quality. It aims to serve government decision-making using information science and technology on the basis of traditional qualitative policy analysis, focusing on ex-ante analysis of specific policy

issues. In contrast, current domestic policy informatics is essentially quantitative analysis of policy texts, focusing on post-hoc quantitative analysis and evaluation of policy outcomes. Therefore, the policy informatics advocated in this paper represents an integration of domestic and international research, combining two developmental directions: the quantitative development of policy science based on policy science in the big data environment, and the development of policy metrics from library and information science. On the one hand, as data volume continues to grow, policy science has gradually begun to borrow methods from other disciplines for policy quantitative analysis, with metrics methods being widely applied to provide robust evidence for government decision-making. On the other hand, as metrics methods and computational methods continue to integrate and penetrate, the research objects of the information science community have gradually expanded from scientific literature data such as papers and patents to policy document data, aiming to reveal the developmental patterns of policy documents.

2.3 Conceptual Definition

Currently, there is no unified understanding in academia regarding the connotation, extension, or core theoretical system of policy informatics. Different scholars have different understandings based on their academic backgrounds and policy contexts, with representative viewpoints shown in Table 1 .

Table 1. Different Conceptual Definitions and System Constructions of Policy Informatics

Category	Representative Viewpoint	Definition/Construction
Conceptual Definition	Y. Kim et al. [20]	Policy informatics is a discipline that uses tools, models, and scenario simulations to help individuals, groups, and communities make policy choices, solve policy problems, and evaluate policy outcomes. Its innovation lies in advancing policy challenge research and policy discussion processes.

Category	Representative Viewpoint	Definition/Construction
	E. W. Johnston et al. [33]	Policy informatics is an interdisciplinary research field that uses emerging modeling and analytical techniques to process massive public policy data to better understand and solve complex public policy and management problems, with the goal of achieving governance process and institutional innovation.
	Liu Hao et al. [44]	Policy informatics is a discipline that takes texts in the policy problem lifecycle as research objects, uses methods and tools from information science, informatics, bibliometrics, and scientometrics to conduct policy knowledge discovery, reveals policy development evolution patterns and characteristics, evaluates policy operation effectiveness and quality, and analyzes policy development hotspots and directions.
System Construction	Duan Zhongxian et al. [45]	Proposed a two-dimensional analytical framework for policy informatics based on policy process and policy networks. In the policy process dimension, policy informatics can optimize policy problems, agendas, decision-making, implementation, and evaluation. In the policy network dimension, policy informatics can provide policy management platforms and more flexible policy tools.

Category	Representative Viewpoint	Definition/Construction
	S. S. Dawes et al. [46]	Policy informatics is mainly divided into three research clusters: policy analysis, infrastructure, and management processes. Policy analysis includes collecting data to provide evidence, visualizing data relationships, and simulating complex problem environments. Infrastructure includes building public institutions related to policy information analysis, designing open and shared decision-making platforms, and participatory platforms for multiple stakeholders. Management processes include introducing technology to optimize processes, transparent management processes, and using network power for collaborative governance.
	Zhang Nan [35]	Policy informatics mainly includes basic analysis methods for public-derived big data, knowledge discovery research around specific policy scenarios, research on policy decision-making models and decision-making process reconstruction strategies for big data, and public choice simulation and decision-making effectiveness evaluation research.

Through analysis of existing definitions and connotations of policy informatics, combined with new development trends, the connotation of policy informatics can be found to mainly include the following aspects: (1) **Research Objects:** Various policy-related issues such as policy subjects, policy objectives, policy tools, and policy processes. (2) **Data Sources:** Large amounts of sci-

entific data generated by policy activities, including but not limited to policy documents such as laws, regulations, and notices; scientific literature such as academic papers and think tank reports; and social media data such as news reports and online public opinion. (3) **Technical Methods:** Mainly borrowing analysis methods and technologies from other disciplines, including bibliometrics and scientometrics, text mining and semantic analysis, and systems science and model building. (4) **Disciplinary Foundations:** Policy science, information science, subject informatics, data science, etc. (5) **Research Purposes:** Conduct knowledge analysis and knowledge discovery in the policy field; Solve increasingly complex public policy and public management problems; Reveal general patterns and characteristics of policy science; Optimize and evaluate policy formulation processes and effects.

Based on the above analysis, policy informatics can be defined as: Policy informatics is a discipline that conducts knowledge mining and knowledge discovery research around key issues in policy science, based on multi-source massive heterogeneous data such as policy document data, scientific literature data, and social media data, using multidisciplinary technical methods from statistics, metrology, and computer science, to better understand and solve increasingly complex policy problems. The core of policy informatics is knowledge analysis and knowledge discovery research on information throughout the entire policy lifecycle, with its three pillars being multi-source data, technical methods, and application scenarios.

Currently, there are two main English interpretations of policy informatics: *Policy Informatics* and *PoliInformatics*. The former is the commonly understood academic term, frequently used in academic papers, conferences, and related forums, while the latter is an integrated expression of the words "policy" and "informatics," appearing in the University of Washington' s Policy Informatics project funded by the U.S. National Science Foundation [47]. Based on the theory of the "X-informatics" discipline group, this paper prefers to use *Policy Informatics* as the formal expression.

2.4 Conceptual Clarification

With the continuous integration and penetration of disciplines, many concepts related to policy informatics have emerged in academia, such as "policy quantification," "policy metrics," "policy document quantification," "policy document metrics,"and "policy science metrics."To clarify the boundaries and relationships between these concepts, a Venn diagram can be used for intuitive representation, as shown in Figure 2 [Figure 2: see original paper].

From the perspective of conceptual inheritance and development, as policy issues become increasingly complex and data scales expand from small samples to big data, policy analysis has gradually shifted from traditional policy quantification to policy metrics and then to policy informatics. From the perspective of conceptual boundaries and scope, policy informatics is a new focus of policy

research in the information revolution. It is a big data paradigm-based, quantitatively oriented policy data analysis and knowledge discovery aimed at solving policy problems. Therefore, policy informatics includes policy document quantification. Policy document quantification conducts statistical analysis of the internal and external features of policy documents. As metrics-related methods mature, policy metrics has gradually become the main research area for policy document quantification. Policy document metrics and policy science metrics are different emphases of policy metrics in policy analysis methods. In fact, whether policy document metrics, policy metrics, or policy document quantification, they all essentially fall within the conceptual scope of policy informatics. Therefore, this paper collectively refers to them as policy informatics.

3. Knowledge Landscape of Policy Informatics

3.1 Research Content

The emergence of policy informatics is an inevitable result of the data-driven scientific research paradigm. Its development not only compensates for the research dilemmas of policy science but also expands the research field of bibliometrics. Through extensive literature review, policy informatics can be found to focus on four main areas:

3.1.1 Research on Policy Change Processes and Evolutionary Patterns

Research on policy change processes and evolutionary patterns is a key focus of policy informatics, encompassing subfields such as policy diffusion, policy change, distribution trends, and attention allocation. First, **policy diffusion and evolutionary pattern research**: C. Huang et al. [48] used bibliometric methods to analyze the issuance of policies by different departments in different periods, 梳理 ing the development 脉络 of China' s science and technology innovation policy system. Subsequently, they proposed a method for analyzing policy topic changes based on the "policy target-policy tool" pattern and validated its effectiveness using policy documents in China' s nuclear energy field [49]. Liu Jianhua [50] and Li Yanping et al. [51] explored the evolution of China' s science and technology policies and talent policies from temporal attributes and perspectives of direct semantic relationships, direct co-occurrence relationships, and indirect co-occurrence associations. Zhang Jian et al. [52] used technology transfer policies as an example and found that policy reference networks and keyword temporal analysis can effectively reveal the diffusion process and characteristics of policies from dimensions of intensity, breadth, speed, and direction.

Second, **policy distribution trends and attention allocation research**: Zheng Ye et al. [53], Qu Zhao et al. [54], and Xi Zhuyan et al. [55] conducted quantitative analyses from the perspectives of policy issuance time, issuing departments, and issuance quantity to depict policy distribution trends. Government attention reflects the degree of importance the government attaches to related policy governance. Wang Gang et al. [56] and Wang Changzheng

et al. [57] analyzed the distribution characteristics and change patterns of government attention based on policy content and social network analysis, using marine environmental governance policies and big data-related governance policies as research objects. D. J. Mallinson et al. [58] explored the process of government attention change using the dynamic changes in U.S. political agenda settings as an example, attempting to provide a comparative perspective on how government institutions shape attention allocation and punctuated equilibrium.

Through the above analysis, it is found that government governance concepts continuously change with the development of political, economic, and social environments. Current research mostly uses quantitative methods to visually present the policy distribution characteristics, diffusion patterns, and historical trajectories of a research field within a certain time period, but has not yet delved into predictive research on future policy development trends.

3.1.2 Research on Policy Quantitative Analysis and Effectiveness Evaluation Quantitative policy evaluation research can provide important theoretical support and decision-making basis for policy formulation, adjustment, and improvement, and has become an important component of policy informatics research in recent years. In 1978, American scholar G. D. Libecap [59] conducted a statistical study on the effects of U.S. mining rights-related regulations and policies, which was the earliest quantitative policy evaluation research. Since then, domestic and foreign scholars have conducted extensive research on quantitative policy evaluation systems. For example, domestic scholar Peng Jisheng et al. [60] constructed a three-dimensional evaluation index system based on policy strength, policy measures, and policy objectives, and developed a specific operational manual for policy quantification standards, which has been widely applied in academia [61-62] and is regarded as a milestone marking the transition from subjective to objective policy quantitative evaluation. Foreign scholar M. A. R. Estrada et al. [63] proposed the PMC (Policy Modeling Consistency) Index based on subjective and objective policy perspectives. Because it can intuitively reveal the strengths and weaknesses of policies under evaluation, it has also been widely applied in policy quantitative evaluation [64-66]. Wu Weihong et al. [67] and Wang Jinfu et al. [68] combined the PMC Index with Auto-Encoder (AE) technology to achieve quantitative evaluation of manufacturing innovation policies and civil-military integration policies. Other commonly used quantitative policy evaluation methods include the AHP Analytic Hierarchy Process [69-70], BP Neural Network Comprehensive Evaluation Method [71], and DEA Data Envelopment Analysis [72-73]. However, the above policy quantitative evaluations are all based on indicator creation, and indicator selection and determination inevitably involve subjective factors. Qie Haituo et al. [74] attempted to apply policy text mining methods to policy evaluation research, analyzing and mining the deep-level information implied in policy texts without selecting indicators to avoid bias from subjective judgment, aiming to compensate for the shortcomings of existing policy quantitative evaluation research.

Currently, from the perspective of policy evaluation practice, research on quantitative policy evaluation methods has gradually reached a considerable scale. However, the increasingly complex policy environment places higher demands on policy evaluation research, with numerous gray and unstructured factors involved. This requires the design of corresponding quantitative evaluation models based on specific policy characteristics to overcome policy failures caused by subjective assumptions and ensure the standardization, completeness, and accuracy of the evaluation process.

3.1.3 Research on Intergovernmental Relations and Policy Games
Policy formulation is inseparable from cooperation and games among policy subjects, and policy implementation is often the result of joint games among multiple government departments. Various government departments form multiple types of intergovernmental relations based on policy formulation or implementation. Intergovernmental relations are the embodiment of government governance mechanisms [75]. As government governance mechanisms become increasingly complex and social network analysis methods mature, quantitative research on intergovernmental relations has become a focus for scholars. It mainly focuses on two aspects: First, **analysis of cooperation patterns and evolutionary patterns of intergovernmental relations**. For example, Y. Sun et al. [76] and Huang Cui et al. [77] extracted structural relationships between government agencies from Chinese science and technology policies and innovation policies, finding that network relationships among policy-making institutions have become increasingly complex, institutional types have become more diversified, and cross-institutional cooperation has become more frequent. Li Xin et al. [78] explored how government departments use various policy tools and their combinations by encoding relevant policy texts and constructing an interactive social network of intergovernmental relations and policy tools to study intergovernmental relations in innovative city construction.

Second, **quantitative research on driving forces and resistance in intergovernmental cooperation**. For example, Liu Xiaoyan et al. [79-80] used Beijing-Tianjin-Hebei science and technology innovation policies as samples, constructed a multi-layer network analysis model of intergovernmental relations from the perspectives of horizontal policy subject relationship characteristics and vertical policy subject diffusion and response characteristics, explored the mechanisms of intergovernmental cooperation within the network, and revealed the driving forces and resistance in intergovernmental cooperation. N. Thompson [81] found that in British national park management, the central government needs to delegate power to grassroots units to allow policy differentiation, which helps promote cooperation among government subjects and ensure the achievement of national policy objectives. Sun Tao et al. [82] and Chen Yu et al. [83] conducted quantitative research on the evolution of environmental governance policies, policy actions, and subject relationship structures from the perspective of intergovernmental relations, analyzing the generation mechanisms of interest games and behavioral deviations of governments in regional environmental

policy implementation processes and exploring the dilemmas hindering regional environmental intergovernmental cooperative governance.

In recent years, regional governance has continuously emerged, and as the dominant actor in the governance process, the impact of intergovernmental relations on regional governance has become increasingly important [84]. However, current quantitative research on intergovernmental relations mainly focuses on describing cooperation patterns, with insufficient exploration of the underlying mechanisms and reasons.

3.1.4 Exploration of the Relationship Between Policy Research and Scientific Research In the policy system, scientific research and government policy formulation present a relationship of mutual influence and coordinated development (see Figure 3 [Figure 3: see original paper]). In this interactive relationship, on the one hand, scientific research provides theoretical explanations and evidence for policy formulation, promoting policy formulation and implementation. On the other hand, the implementation of various government policies can become academic guidance, promoting the development of scientific research. In this interactive relationship, think tanks, as the "eyes, ears, and advisors" of government departments, are also an indispensable part of the policy system. Many scholars have conducted quantitative research on the mutual influence among various entities. For example, P. Bakhtin et al. [85] used the agriculture and food sector as an example, proposed a "trend monitoring" method based on semantic analysis to calculate the similarity between scientific research and policy documents, and proved that the influence between scientific research and policy formulation is mutual—scientific literature can influence policy formulation, and vice versa. Fang Junzhi et al. [86] studied the thematic change characteristics of literature and policies in the PPP (Public-Private Partnership) field and found that the interactive relationship between policies and literature varies in different development stages. Zhao Yifang et al. [87] used the public cultural service field as an example to explore the consensus and divergence between theoretical research and policy formulation, while raising the question of whether the leading relationship between theoretical research and policy formulation is "theory serving policy" or "policy subordinate to theory."

In traditional thinking, people usually believe that theoretical research guides policy formulation, and the most ideal relationship between the two is "evidence-based policymaking." To this end, some scholars have embarked on the path of seeking evidence. For example, Y. Yian et al. [88] tracked the citation relationship between policies and papers during the COVID-19 pandemic and found that most policy documents cited the latest, peer-reviewed, high-impact academic achievements to a large extent, and policy documents that cited academic achievements had higher influence, manifested by being more easily cited by other policies. Shi Qian et al. [89] used informatization policies and theoretical literature as research objects, revealed changes in thematic concepts by counting keyword frequencies in different time periods, and concluded that research

theory lags behind policy. In fact, this article assumes the premise that "theory serves policy." If this premise is ignored, the timeliness lag found in the research might also be understood as side evidence of "policy subordinate to theory." Therefore, the relationship between scientific research and policy research is not a simple linear relationship but an interactive relationship of mutual influence and mutual promotion.

Additionally, think tanks are usually non-profit research and consulting institutions that focus on strategic issues and public policy, serving the purpose of providing scientific, democratic, and law-based decision-making for the Party and government [90]. They have a strong policy-advisory color and a close relationship with policy formulation. Think tank research results can be considered as data samples for policy prediction. For example, Liu Hao [91] used U.S. government policies and think tank research results in the cybersecurity field as examples, calculated the temporal intensity of topic clustering for correlation testing, and attempted to predict future policy development trends for the theme of "Asia-Pacific cybersecurity and development," finding that there is a certain correlation between think tank research and policy development, confirming the feasibility of conducting policy prediction research from the think tank perspective. Currently, research on policy development trend prediction is still relatively scarce and mostly concentrated on presidential election prediction research, while research on the interactive relationship between think tank results and policy formulation has not yet emerged, which may be an effective path for future policy prediction research.

3.2 Research Process

The research process of policy informatics is a linear transformation process from policy data to knowledge, as shown in Figure 4 [Figure 4: see original paper]. First, effective information is extracted from multi-source heterogeneous data, then various technical methods are used for data mining, and finally, the results of knowledge analysis are applied to specific policy research scenarios. Among them, policy problems are both the application scenarios for policy informatics research results and the driving factors for conducting policy informatics research.

3.2.1 Multi-Source Heterogeneous Data The research foundation of policy informatics is massive multi-source heterogeneous data. Since the implementation of the *Regulations on Open Government Information of the People's Republic of China* in May 2008, government information has gradually shifted from focusing on open sharing to focusing on data utilization [92]. However, due to differences in data types, data standards, and data scopes of policy information resources, there is currently no mature policy database or domain-specific policy database. Scholars mostly collect data independently from various government official websites to form datasets needed for research. Commonly used policy databases are shown in Table 2 .

Table 2. Policy-Related Data Platforms

Platform	Description
PKULaw (http://www.pkulaw.cn/)	An intelligent one-stop legal information retrieval platform, including laws and regulations, judicial cases, law journals, law firm practices, thematic references, and other types of legal information.
Chinese Government Website (http://www.gov.cn/)	A comprehensive platform for the State Council and its departments and the people' s governments of provinces, autonomous regions, and municipalities directly under the Central Government to release government information and provide online services on the Internet, mainly including important policy documents, speeches by leaders, and planning reports.
Overton (https://www.overton.io/)	The world' s largest searchable index of policy documents, guidelines, think tank publications, and working papers, collecting data from 182 countries and over 1,000 sources worldwide, and associating it with relevant news reports, academic research, think tank outputs, and other related policies.
Tsinghua University Policy Document Center (http://www.sppm.tsinghua.edu.cn/zcpt/zfwx/)	A self-built database of the Tsinghua University Center for Science and Education Policy Research, which defines the data scope based on a two-dimensional orientation of academic value of government documents and public management discipline construction value, including central government policy documents, government bulletins, work reports, and government public publications from 1949 to the present.
American Presidency Project (https://www.presidency.ucsb.edu/presidents)	The authoritative source for U.S. presidential public documents, including executive orders, proclamations, press releases, State of the Union addresses, and conference speeches, while providing data analysis functions and mapping them onto U.S. maps to vividly depict voting situations.

Platform	Description
Pennsylvania Policy Database (https://www.cla.temple.edu/pennsylvania-policy-database-project/datasets/)	Includes behavioral data on the legislature, governor, state supreme court, media, and public opinion. Data is encoded using 22 major topic codes and nearly 250 sub-topic codes similar to related projects, adjusted for national policy responsibilities. Includes more than 10 policy datasets such as Governing Magazine, Newspaper Clips, Bills, Resolutions and Laws, Legislative Hearings, Legislative Service Agency Reports, Governors' Budget Addresses, Executive Orders, Supreme Court Decisions, Most Important Problems Polls, and Budget for open-source use.

It can be seen that compared with mature specialized informatics such as bioinformatics and patent informatics, policy informatics databases are still in the development stage. Data analysis platforms and tools lack specificity, and the functions for data analysis and knowledge discovery oriented toward specific policy problems are not yet perfect. In fact, current policy data analysis platforms mainly focus on simple statistical analysis of policy-related data, while substantive content mining and semantic sentiment analysis of policies remain at the theoretical level.

3.2.2 Data Analysis Methods Commonly used data analysis methods in policy informatics include bibliometric analysis, social network analysis, content analysis, text mining, and visualization methods. Different analysis methods correspond to different analysis tools, as shown in Table 3 . Main tools include: CiteSpace, VOSviewer, and other bibliometric and visualization tools; Ucinet, Pajek, SCI2, Gephi, and other social network analysis tools; Python, R, and other programming tools; and N-Vivo and other semantic analysis tools.

Table 3. Common Analysis Methods in Policy Informatics

Method	Description	Common Tools	Application Scenarios
Bibliometric Analysis	Typically takes scientific literature systems and document features as research objects, analyzing distribution structures, quantitative relationships, change patterns, and quantitative management of literature to explore scientific structures, characteristics, and patterns [96].	Excel, SPSS, BibExcel, CiteSpace	Research on policy distribution patterns such as issuing bodies, issuance time, and research subjects.

Method	Description	Common Tools	Application Scenarios
Social Network Analysis	Constructs a relationship network of key themes and issuing bodies in policy documents, divided into cooperation networks and topic association networks. Cooperation networks can reflect relationships between government subjects; topic association networks can reveal hotspots and frontier research in policy fields.	Ucinet, Pajek, Gephi, SCI2, NetDraw	Research on intergovernmental relations and topic clustering.

Method	Description	Common Tools	Application Scenarios
Content Analysis	Quantifies policy document content, processes unstructured information in policy texts into structured knowledge units, forming easily readable and analyzable knowledge units. Essentially, it is quantitative analysis based on qualitative content, with non-intrusive, objective, and neutral characteristics.	Python, R, N-Vivo	Policy content semantic analysis, political stance analysis.
Text Mining	Uses policy coding, policy concept vocabularies, or mapping relationships between policies and words for automatic identification and processing of policy concepts, constructing an automatic analysis framework from policy texts to semantics [97].	Python, R	Topic change and evolution, policy diffusion, policy prediction research.

Method	Description	Common Tools	Application Scenarios
Visualization	Uses visualization tools to intuitively express policy themes, cooperation relationships, and change and evolution processes in the form of "knowledge maps," usually requiring combination with other methods.	CiteSpace, VOSviewer	Policy knowledge mapping, intuitive presentation of research results.

In practical applications, scholars usually comprehensively use multiple methods to achieve systematic and holistic research on policy documents. For example, Wu Bin et al. [98] and Wang Fang et al. [99] comprehensively used bibliometric methods and content analysis to analyze China' s marine engineering equipment manufacturing industry policies and rural informatization policies, respectively, revealing the historical evolution, focus areas, and cooperation status of issuing bodies. In the context of the big data era, using large-scale data and text mining methods to study policy content is regarded as a data frontier [100]. Big data-related technologies can quickly and non-persistently match and link related but heterogeneous information fragments, helping to identify hidden patterns and correlations between information flows that have not yet emerged, improving the quality of scenario planning and predictive analysis, and leading to true evidence-based decision-making. Many scholars are committed to deepening policy text mining methods. For example, M. N. Dedaic' [101] improved the efficiency of information extraction and feature recognition through machine learning, providing technical support for policy topic analysis and hotspot identification. Zhang Tao et al. [102] proposed a policy text mining method that integrates keyword extraction, topic analysis, and co-occurrence analysis, mainly used for extracting policy content analysis frameworks and analyzing policy documents and policy comments. W. Y. Chuang et al. [103] focused on social media sentiment semantic analysis, developing a social media-based public policy informatics framework—the iMood system—to promote automatic social media analysis. Wei Yu et al. [104] introduced natural language processing into policy quantification research, using word segmentation, part-of-speech tagging,

named entity recognition, and dependency parsing to construct a "time-space-subject-element-topic" policy quantification model based on semantic analysis.

Due to current limitations in policy databases, corpora are still lacking in timeliness and completeness, resulting in text mining methods not yet being fully deployed in the policy analysis field. However, policy text mining is a direct semantic expression of policy information, involving technologies such as text mining, machine learning, and natural language processing. It is a more refined policy metrics analysis method [105]. It can be foreseen that as policy documents become increasingly abundant and related technologies mature, policy text mining will have broad application space.

3.2.3 Knowledge Analysis and Discovery Policy informatics not only requires advanced information technology to make government data more usable but also requires specialized research teams to conduct comprehensive and objective analysis of information to transform data into knowledge for solving policy problems. Therefore, policy analysis and interpretation are key steps in policy informatics. However, it should be noted that information is objective, while understanding is subjective. With the open data movement and the popularization of social media, information resources have become more complex and diverse. Analysts understand information processed by various technical methods according to their own knowledge systems and values, and ambiguity is widespread. For the same policy problem, there are often multiple methods and paths for policy analysis, and using different analytical approaches may lead to different research results. This requires researchers to have a deep understanding of the advantages and limitations of different data analysis techniques and tools; otherwise, there is a risk of deviating from the analysis process [106]. Currently, knowledge discovery based on multidisciplinary technical methods cannot yet be effectively linked to the formation of valuable practical policy problem solutions. Therefore, how to draw objective conclusions from objective information is a key issue that policy informatics needs to solve in the future.

3.3 System Construction

In the early stages of disciplinary development, building a disciplinary system with a clear theoretical structure and comprehensive scientific content is crucial. Based on the main research content and methods of policy informatics, combined with the growth process of disciplines from emergence to maturity, this paper establishes a disciplinary system including four aspects: theoretical foundation, methodological techniques, application practice, and education management (see Figure 5 [Figure 5: see original paper]), aiming to comprehensively demonstrate the development 思路 of policy informatics.

The development of policy informatics appears to be a linear relationship among theoretical foundation, methodological techniques, application practice, and education management, but in reality, each pair mutually promotes and cross-fertilizes, forming a complete cycle. Among them, the theoretical foundation

is the basis for the emergence and development of policy informatics, methodological techniques are powerful tools for its development, application practice is the ultimate result and development goal, and education management is the inexhaustible driving force for disciplinary development, continuously providing talent for policy informatics and enabling the inheritance and development of policy informatics knowledge. Overall, these four aspects are both independently developed and mutually promoting, forming a closed organic development cycle that fully reflects the comprehensiveness, rationality, and scientific nature of policy informatics development.

4. Future Prospects of Policy Informatics

Policy informatics is, to a certain extent, policy quantitative analysis research, but compared with traditional policy quantitative analysis, it pays more attention to correlation rather than causation. It is a large-sample knowledge discovery process rather than a small-sample statistical inference analysis, providing objective and comprehensive decision-making basis for policy participants (policymakers and stakeholders), promoting the transformation of relevant governments from empirical governance to data governance, from post-hoc management to ex-ante prediction, and from passive supervision to active monitoring. It may become one of the important disciplinary foundations of policy science in the future. Based on this, this paper proposes the following development directions:

4.1 Building Specialized Domain-Specific Policy Big Databases

Currently, the construction of policy data resource systems is still in its infancy, with relatively low data volume, scope, and degree of structuring, especially lacking specialized domain-specific policy big databases. The government should accelerate the construction of policy big data integration and analysis platforms oriented toward solving policy problems and serving policy formulation, aggregating all types of policy-related information, promoting data integration and sharing, and building specialized policy fact databases, text corpora, etc., to promote the construction of one-stop modern platforms for data collection, management, analysis, and visualization, thereby providing a good data and tool foundation for the prosperous development of policy informatics. Special attention should be paid to the fact that policy informatics is a problem-driven discipline. Only by building professional domain-specific policy databases can specialized policy analysis be supported, which can specifically reveal policy knowledge and evolution trajectories hidden behind policy information, verify empiricism and subjective judgments in qualitative research, visually present policy trends, and predict patterns, helping to solve specific policy research problems.

4.2 Developing Specialized Policy Analysis Techniques and Tools

Policy documents are similar to scientific research documents in that they have basic structural elements and policy semantic content, but they also have their own unique characteristics. First, policy documents, based on their unique political attributes, usually have higher knowledge density and more standardized discourse systems. Second, the relationships between policy documents are more complex, and complex intergovernmental relationships may cause policy texts to present continuous, combined, and complementary network relationships. Third, policy issuance has periodicity, and policies issued in different periods usually have different thematic focuses. Based on such particularities, existing analysis techniques and tools are inadequate. This requires continuous innovation and integration while borrowing from other disciplines' technical methods, developing targeted technical methods and professional data analysis tools suitable for policy informatics research, to mine classification or clustering features, discover associated knowledge and patterns from large amounts of unstructured and semi-structured policy text data sets, and advance from external attributes of documents to policy text content analysis, semantic analysis, and sentiment analysis, promoting precise analysis of multi-source massive data.

4.3 Conducting Case Studies Around Specific Policy Scenarios

The rise and development of a new discipline are the result of continuous iterative evolution of theoretical research and practical testing. Only by conducting extensive theoretical and practical research oriented toward problems and needs can policy informatics continue to develop. Currently, there are relatively few mature research cases on solving actual policy problems. Next, it is necessary to conduct case studies around specific policy scenarios and specific research fields to discover key knowledge that is truly valuable for policy decision-making, policy evaluation, and policy prediction processes from massive policy data. The difference between policy informatics and other specialized informatics is that it involves a wide range of disciplinary fields, such as science and technology policy, ecological policy, digital policy, information policy, and artificial intelligence policy. Especially in the post-pandemic era, building key domain policy databases and conducting policy case analysis for major national strategic fields is particularly important. On the one hand, it can improve the theoretical foundation of policy information and test qualitative research conclusions; on the other hand, it can provide valuable experience for conducting more extensive policy informatics research.

4.4 Promoting the Development of Policy Informatics Academic Communities

In 2007, Arizona State University established the Center for Policy Informatics with the goal of building a research community to explore the impact of advanced information technology on public policy [107]. However, despite the continuous growth of policy information activities accelerating the aggregation

of researchers and the accumulation of research results in this field, it has not yet become a hot research area, and there are few influential academic communities. In today' s increasingly complex policy research issues, each research field should form a professional policy information analysis and decision-making consultation team to meet the development needs of policy science in various disciplines and provide strategic references for solving related scientific problems. At the same time, with the development of information technology, academic exchanges in policy informatics can shift to more interactive and collaborative models, including developing partnerships among public managers, policymakers, interest groups, and any members of civil society and private sector organizations, forming online academic communities such as online communities and network forums to address continuously changing and complex policy challenges.

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CAO Lingjing: Conducted literature research, collation, and analysis; wrote and revised the paper.

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Abstract: [Purpose/significance] The theoretical framework and development path of policy informatics are systematically combed and summarized, which can lay a solid theoretical and methodological foundation for related research in policy science, bibliometrics, and other fields. [Method/process] Relying on subject informatics, this paper clarifies the development origin and conceptual connotation of policy informatics, summarizes its research content and process in detail, proposes a disciplinary system centered on four mutually reinforcing aspects— "theoretical foundation, methodological techniques, application practice, and education management" —and constructs a research system for policy informatics from the perspectives of theoretical foundation building and knowledge mapping. [Result/conclusion] Policy informatics mainly focuses on massive multi-source heterogeneous data, using methods such as bibliometric analysis, social network analysis, content analysis, text mining, and visualization to study policy change processes and evolutionary patterns, conduct policy quantitative analysis and effectiveness evaluation, examine intergovernmental relations and policy games, and explore the relationship between policy research and scientific research. Future development requires building specialized domain-specific policy databases, developing dedicated policy analysis techniques and tools, conducting extensive and in-depth case studies, and forming high-quality academic communities.

Keywords: policy informatics; policy quantification; policy metrics; interdisciplinary; subject informatics

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