

Postprint: A Study on the Endogenous Value of Digital Libraries and Their Knowledge Spillover Effects

Authors: Mao Ganming

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Abstract

[Purpose/Significance] This study classifies and differentiates digital libraries, and constructs a basic model for the endogenous value of digital libraries and their knowledge spillover effects using endogenous growth theory. [Method/Process] Domestic and international digital libraries are divided into three major stages (development, storage, application) and seven modules, upon which empirical analysis of endogenous variables and holistic analysis are conducted. [Results/Conclusion] The knowledge spillover of digital library network systems exhibits global effects.

Full Text

Preamble

**ChinaXiv Cooperative Journal: Academic Exploration
Research on the Endogenous Value and Knowledge Spillover Effects
of Digital Libraries**

Mao Ganming

Library of Gannan Normal University, Ganzhou 341000

Abstract

[**Purpose/Significance**] This study screens and classifies digital libraries and constructs a basic model of digital library endogenous value and its knowledge spillover effects using endogenous growth theory. [**Method/Process**] Digital libraries at home and abroad are divided into three major segments (development, storage, and application) and seven modules for empirical and holistic analysis of endogenous variables. [**Result/Conclusion**] The knowledge spillover of digital library network systems exhibits global effects.

Keywords: digital library, endogenous growth, knowledge spillover, intellectual property, tacit knowledge

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1 Overview

Endogenous growth theory, which emerged in the mid-1980s as a branch of Western macroeconomic theory, posits that economies can achieve sustained growth without external impetus, with endogenous technological progress serving as the decisive factor. Technological advancement generates various effects during knowledge spillover processes, including chain effects, driving effects, imitation effects, communication effects, incentive effects, and competition effects. The endogenous value variables and knowledge spillovers of high-tech enterprises and brands exert sustained multiplier effects on socioeconomic development (exemplified by companies such as Microsoft, Google, and Apple).

Both knowledge spillover and knowledge dissemination represent forms of knowledge diffusion, yet they differ fundamentally: dissemination involves knowledge replication, whereas spillover entails knowledge recreation. Knowledge spillover and its effects constitute focal research topics in new economic growth theory, new trade theory, and innovation economics. As research on endogenous growth theory has deepened, economists have recognized that its greatest challenge lies in empirical analysis. Whether following Romer's approach through independent R&D departments or Lucas's approach through human capital spillovers, researchers face the common problem of conducting empirical studies on the three endogenous variables in endogenous growth models: endogenous savings rates, endogenous labor supply, and endogenous technological progress. After three decades of development, endogenous growth theory models have become reasonable theoretical tools for explaining modern economic growth phenomena.

In recent years, domestic research on endogenous growth theory and practice has approached the topic from perspectives such as endogenous variables, replicability, incentive factors, growth paths, and institutional change, covering social domains including management, finance, fiscal policy, regional development, trade, industrial structure, energy, and urbanization. Targeted specific research and case analyses represent the vitality and prospects for the theory's in-depth development. However, applying this theory to digital libraries remains rare. Since digital libraries have become integral components of the network economy, network knowledge organization, and network information sources, they are clearly amenable to endogenous growth theory research. Only through systematic modeling to clarify the internal, external, and holistic structural relationships of digital library network systems can we conduct empirical analyses of digital library endogenous growth and knowledge spillover effects.

2 Digital Library Classification and Identification

To construct a basic model of digital library endogenous value and knowledge spillover effects, we must first classify and characterize various digital libraries within the network system. This facilitates understanding of knowledge sources, knowledge organization, knowledge innovation, knowledge diffusion, knowledge value, and knowledge flow directions, while also enabling analysis of the relationships among internal structures, external structures, and overall structures of subsystems within the digital library network system. Currently, there exist over one hundred definitions of digital libraries, each with specific applications. However, based on operational nature, they can be divided into three categories: (1) commercial digital libraries primarily developed for profit by developers; (2) public digital libraries primarily providing free public services based on traditional physical libraries; and (3) all digital libraries that utilize digital library technology to provide digital resource services.

With the deepening development of globalization, networking, and integration, these three types of digital libraries increasingly permeate and interconnect with one another, gradually converging toward unified technical standards, value reciprocity, and knowledge sharing. Interest distribution is primarily balanced through intellectual property law. Due to different operational methods and objectives, each type of digital library has distinct and complementary social divisions of labor. Most notably, commercial and public digital libraries differ in knowledge acquisition channels, operational methods, and service purposes, with cross-interaction of endogenous variables leading to distinctive characteristics in endogenous knowledge growth and knowledge spillover effects.

2.1 Commercial Digital Libraries

Commercial digital libraries refer specifically to those developed by developers for profit. They exist universally across countries, varying in scale, and have developed rapidly in developed countries through industrialized operations closely associated with the knowledge economy. Their economic and social benefits are directly proportional to national political, economic, technological, educational, cultural, and networking development levels.

The social value of commercial digital libraries manifests in their use of entirely new equipment and technologies for development, objective business and market forecasting for positioning, and the capture of potentially valuable information through forward-looking perspectives and rapid, accurate means and channels. They plan, collect, organize, store, and develop this information and knowledge to form new knowledge products such as software, commercial databases, and on-line publications, providing required knowledge products to various social institutions and individuals and offering knowledge guarantees for social knowledge innovation and technological innovation. These knowledge products themselves represent achievements in knowledge and technological innovation by commercial data developers and commercial digital library operators in the network

environment. Practice demonstrates that leading enterprises, consulting firms, publishing and media giants, distribution and intermediary companies, scientific research and technology centers, and intelligence research centers across many industries have all developed and constructed commercial digital libraries that provide paid services to society. These commercial digital libraries maintain intricate connections with one another.

Corporate planning companies and various research centers also intentionally provide advice for enterprises transitioning into or establishing digital libraries. For instance, the China Industry Research Institute provides forecasting reports and implementation plans for enterprises investing in commercial digital libraries. The most significant characteristic of these reports is their forward-looking and timely nature. Based on the development trajectory of the Internet-plus-digital-library industry and years of practical experience, the reports provide prudent analysis and predictions of future development trends in the Internet-plus-digital-library industry. They represent essential resources for digital library enterprises and investment firms to accurately understand the latest developments in business model innovation within the industry, seize market opportunities, make correct business decisions, and clarify corporate development directions. The report points out that competition in the Internet-plus-digital-library industry has entered the business model competition stage. Whether Internet giants' investment layouts in the digital library domain, listed digital library enterprises' Internet transformation, or startups' entrepreneurship in this field, all focus on business model innovation in investment projects. Enterprises that have achieved success in business model innovation have risen rapidly to become leaders in the Internet-plus-digital-library industry. The report comprehensively analyzes the economic background, related industrial background, and technological background of China's Internet-plus-digital-library industry. For example, its analysis of industry technological background involves four aspects: (1) current development status and future trends of cloud computing technology; (2) current development status and future trends of Internet of Things technology; (3) current development status and future trends of communication technology; and (4) summary of the impact of Internet-related technologies on the industry [1].

2.2 Public Digital Libraries

Public digital libraries refer to public digital libraries, university digital libraries, professional digital libraries, and other non-commercial digital libraries that have evolved from traditional physical libraries while maintaining primarily free public services. Libraries are not merely physical concepts but also digital, networked, virtual, mobile, and ubiquitous. Digital libraries can be understood in narrow and broad senses: the narrow sense refers to the technology itself, while the broad sense encompasses commercial digital libraries, public digital libraries, and all other types of digital libraries. Logically, this represents a dis-

inction between connotation and extension. The narrow-sense digital library constitutes the technological connotation and foundation of all digital libraries, whereas the broad-sense digital library represents a classification based on different operational methods, purposes, and technical standards—an extension of the digital library concept.

Rather than saying that public digital libraries exist in correspondence with commercial digital libraries, it would be more accurate to state that commercial digital libraries represent an extension of traditional library functions. Conversely, the successful application of digital technologies by commercial data developers has enabled successful integration of commercial digital library technology and resources to meet traditional library needs. When traditional libraries purchase knowledge products and services from commercial digital libraries, they also acquire or develop their own digital technologies and equipment, particularly in the Internet era, which has become an inevitable choice for traditional libraries. Therefore, from the perspective of digital technology marketization, the development of public digital libraries is an inevitable result of commercial digital library technology's market penetration into libraries. Whether an inevitable choice or an inevitable result, the reality is that each contains elements of the other, and neither can exist independently. Analyzed through endogenous economic theory, both commercial and public digital libraries represent concrete manifestations of digital library technology and knowledge spillover, reflecting the comprehensive economic and social benefits in the network economy.

2.3 Other Digital Libraries

Other digital libraries refer to all digital libraries that utilize digital library technology to provide digital resource services. Internet Service Providers (ISPs) can be divided into Internet Access Providers (IAPs) and Internet Content Providers (ICPs). In a sense, IAPs serve as the necessary gateway for billions of users worldwide to access the Internet, while ICPs publish comprehensive or specialized information on the Internet and generate profits through advertising fees and user registration charges. These active intermediaries on the Internet provide extensive and convenient operational channels and methods for various digital libraries.

Currently, various entities or virtual institutions utilizing digital library technology to provide digital resource services have complex compositions, varying scales, and are characterized by specialization, practicality, flexibility, and marketization. Internal digital libraries within enterprises involve internal knowledge management, trade secrets, product development, market forecasting, competitive intelligence, and other non-public information resources for internal communication. What information they publish or keep confidential is entirely autonomous corporate behavior subject to intellectual property protection.

3 Basic Model of Digital Library Endogenous Value and Knowledge Spillover Effects

Digital libraries have become integral components of the network economy, network knowledge organization, and network information sources. Therefore, their basic structure resembles that of the Internet: distributed rather than simple geographical layouts, representing dynamic real-time arrangements among countless digital libraries. Simultaneously, they form close relationships with commercial data developers, commercial digital library technology developers, network operators, and publishing intermediaries. Based on the endogenous variables provided by endogenous growth theory models, digital library endogenous variables can be summarized into three aspects: (1) digital library endogenous knowledge growth; (2) digital library endogenous human capital; and (3) digital library endogenous technological progress. Modeling and empirical analysis can be conducted accordingly.

3.1 Modeling

To facilitate empirical analysis, the author divides digital libraries at home and abroad into three major segments and seven modules. The three segments refer to digital library development, digital library storage, and digital library application. The seven modules comprise: (1) international digital library data and digital technology development; (2) international digital library application; (3) domestic digital library data and digital technology development; (4) domestic commercial digital library operation; (5) domestic government and institutional digital library funding and knowledge management; (6) domestic public digital library application; and (7) digital library user cross-national services, paid services, and free services. The basic model of digital library endogenous value and its knowledge spillover effects is shown in [Figure 1: see original paper].

4.1 Digital Library Endogenous Knowledge Growth

Digital library endogenous knowledge growth includes both overall growth and specific growth.

4.1.1 Overall Growth

Within digital library network systems, overall endogenous knowledge growth occurs due to the externalities of knowledge. In the knowledge economy environment, when one party provides services to another, it simultaneously generates benefits or losses for a third party. As beneficiaries, third parties do not pay compensation; as victims, they receive no compensation. These consequences, not reflected through monetary or market transactions, are not borne by the interacting parties and thus constitute external effects [4]. Particularly for commercial data developers and commercial digital library technology developers, newly invested knowledge products and technologies exhibit spillover effects.

Not only can investing firms improve productivity through accumulated production experience, but other firms can also enhance productivity through learning. Consequently, other domestic and international developers in the same industry or relevant parties in the same field or system all gain inspiration from knowledge and technological innovation, learn from one another, increase knowledge, and improve the overall economic and social benefits of digital library systems or fields.

4.1.2 Specific Growth

Specific digital library endogenous knowledge growth includes growth in both explicit and tacit knowledge. Explicit knowledge is clearly expressible knowledge that can be disseminated through language, books, text, databases, and other encoding methods, making it easy to process, transfer, and store. Various digital libraries can track explicit knowledge development by introducing online databases or updating self-built databases, and can integrate explicit knowledge with existing knowledge systems to construct new knowledge systems or units, or develop new application approaches for existing explicit knowledge, such as digitizing print books, building characteristic databases, creating various document, image, and data collections, and conducting activities like document delivery, interlibrary loan, union catalogs, and joint procurement of literature resources. The endogenous value of these activities lies in achieving explicit knowledge sharing.

Tacit knowledge typically refers to knowledge that is difficult to express clearly, highly personalized, and exists in human minds, including experience, know-how, ideas, and feelings. Consequently, it cannot be freely transmitted through networks and communication technologies like explicit knowledge. Specific digital libraries can acquire tacit knowledge growth through visits and study tours, training, specialized forums, academic seminars, talent mobility, collaborative R&D, and informal interpersonal interactions, maintaining frequent contact with experts and technical sites in the digital library field to bring continuous “technology flow,” “information flow,” “experience flow,” and “knowledge flow” [5].

In the multimedia environment of digital libraries, the boundary between explicit and tacit knowledge becomes less distinct. Primarily, this is because audio, video, images, animation, text, data, and cross-regional, cross-temporal instant links shorten interpersonal distances, prompting the emergence of a third state in knowledge classification: a comprehensive state of explicit and tacit knowledge. Various academic exchange platforms, consulting platforms, retrieval platforms, human-computer dialogue, knowledge linking, immersive technologies, animation analysis, and academic reports have significantly increased the possibility of long-distance tacit knowledge transmission, while also increasing the potential for R&D knowledge spillover and human capital spillover.

4.2.1 Human Capital Value

In contemporary society, human capital exists as a value system that continuously evolves amid socioeconomic structural changes. Its external manifestation is a social relationship, while its essence represents a higher form of capital within human-dominated social relationships. Human capital value refers to all necessary expenses for maintaining human capital reproduction, comprising both explicit and implicit human capital. Compensation is often considered the most accurate monetary measure of human value and contribution, belonging to explicit human capital. However, some human capital information that cannot be measured in monetary terms—such as ability, character, work enthusiasm, professional reputation, social status, entrepreneurial spirit, and corporate loyalty—also constitutes important content of human capital value, belonging to implicit human capital value.

As knowledge-intensive enterprises and industries, digital library fields concentrate large numbers of high-quality innovative and technical talents in development, storage, and application segments. These individuals primarily engage in intellectual labor. Only by stimulating their implicit human capital can they create value higher than explicit human capital. The actual utilization degree of implicit human capital depends on reasonable measurement and incentives for its value and contribution. Human capital management and incentive mechanisms are applicable to knowledge management and knowledge capital management.

4.2.2 Knowledge Capital Management

Knowledge capital theory represents a school of thought within endogenous growth theory, emphasizing the important role of people in enterprise knowledge capital composition. It distinguishes knowledge into encoded and non-encoded knowledge. Encoded knowledge constitutes existing enterprise knowledge assets—explicit knowledge—while non-encoded knowledge exists dependent on individual employees—tacit knowledge. Essentially, tacit knowledge reflects individual comprehensive capabilities. Therefore, motivating employees to transform personal non-encoded knowledge into enterprise-encoded knowledge for organizational and team sharing represents the key to enterprise knowledge and technological innovation. Only by being people-oriented can organizations utilize knowledge to create value. Knowledge capital theory posits that knowledge capital = human resources (non-encoded knowledge) + structural capital (encoded assets and operational assets) [6].

The concept of knowledge capital expands the notions of material and non-material capital, revealing what is truly valuable to enterprises and organizations: assets based on employee and organizational skills and knowledge. This points organizations in the correct operational direction. Knowledge management involves maximizing benefits based on one's own innovation achievements and fully benefiting from others' inventions within legal boundaries [7]. Since

knowledge assets are intangible and possess enormous “spillover effects,” with beneficiaries often being individuals or organizations other than those investing in the intangible assets, the law implements intellectual property protection for enterprises’ important knowledge assets to ensure they receive sufficient returns from developing such knowledge products, thereby promoting the growth of enterprise endogenous value.

4.2.3 Government Decision-Making and Policy Regulation

In regulating and guiding high-tech policies, governments emphasize both enterprise intellectual property protection and utilization of knowledge and technology “spillover effects” to improve economic and social benefits brought by technological progress. This explains, from one perspective, the formation and development of enterprise clusters and their innovation advantages. This is why some scholars emphasize the importance of reciprocal social networks within geographical regions for facilitating mutual exchange among scientific and technical personnel and promoting knowledge spillover and diffusion, as exemplified by Silicon Valley in the United States and high-tech development zones across China.

In the network environment, the impact of digital library endogenous human capital and technological spillover on implicit human capital value clearly shows an overall increasing trend for digital library endogenous human capital value.

4.3.1 Endogenous Growth from a Technical Perspective

Since the 1990s, growth theorists have studied economic growth issues under monopolistic competition assumptions, proposing new endogenous growth models. These models can be divided into three types based on different understandings of technological progress: product variety expansion models, product quality upgrading models, and specialization deepening models. The proposal of these three model types indicates that endogenous growth theory has entered a new developmental stage.

In terms of technological progress, digital libraries primarily involve digitization technology, large-scale database technology, network technology, multimedia information processing technology, information compression and transmission technology, distributed processing technology, security and confidentiality technology, reliability technology, data warehousing and online analytical processing technology, information extraction technology, data mining technology, content-based retrieval technology, natural language understanding technology, etc. These technological advances are closely related to Internet technological progress and macroeconomic regulation, with endogenous technological progress variables following principles similar to endogenous knowledge growth and endogenous human capital.

4.3.2 International Digital Library Research Perspective

Based on literature and keyword statistical analysis, current research on international digital libraries has formed nine knowledge clusters: (1) information visualization and data mining research; (2) database and data storage research; (3) user research and personalized services; (4) information services and information management research; (5) information retrieval and other technical issues research; (6) electronic publishing and digitization issues research; (7) academic and university libraries and library management research; (8) digital library usability and evaluation research; and (9) mobile library research.

The knowledge network of international digital libraries exhibits obvious discrete-tight-discrete structural characteristics. Over the past 15 years, the knowledge network of digital library research has undergone significant changes—after a relatively rapid aggregation process, it quickly matured and began refining, with faster selection speeds for knowledge individuals and shorter lifecycle fluctuation intervals. The nine knowledge clusters of the international digital library knowledge ecosystem maintain close relationships, with strong interactive cultivation between clusters and strong synergy among higher-status knowledge clusters. The migration and changes of each knowledge cluster vividly demonstrate evolutionary characteristics such as knowledge metabolism, cross-penetration, and knowledge ecology [9], reflecting the extensive social impact of digital library endogenous technological progress and knowledge spillover.

4.4.1 Overall Model

From an overall perspective, the digital library network represents one component of Internet system engineering under the global intellectual property protection framework, belonging to the network economy and forming a knowledge alliance linked by countless knowledge organizations worldwide. Regarding digital library system engineering, in the network environment, market behaviors such as knowledge reorganization, knowledge innovation, knowledge storage, and knowledge transfer can only ensure that knowledge products and commodities generate value and use value in transactions under intellectual property protection, which constitutes the basic premise for developing a knowledge economy.

From a holistic systems perspective, the model divides the digital library network into seven relatively independent modules: international digital library data and digital technology development, international digital library application, domestic digital library data and digital technology development, domestic commercial digital library operation, domestic government and institutional digital library funding and knowledge management, domestic public digital library application, and digital library user cross-national services, paid services, and free services. These modules form complex relationships through Internet links, with their essential connections completing the exchange and interaction

of knowledge value and use value through market transactions of capital flow, information flow, and technology flow. This process completes the endogenous growth of each system module, generating economic or social benefits. Due to the external characteristics of knowledge (shareability), this knowledge exchange interaction and value exchange creates chain knowledge spillover effects within the overall system, successively benefiting non-transacting parties and ultimately benefiting user groups to achieve social benefit maximization.

4.4.2 Relationships Between Modules

As shown in [Figure 1: see original paper], each module constitutes a relatively independent subsystem with its own internal structure, forming internal and external relationships with other modules. Each specific digital library serves merely as a node within the macro digital library cluster network. On the Internet, relationships between specific digital libraries are mutually source and destination relationships. The relationship between the macro digital library network and user groups essentially represents a cyclical, cumulative, and interactive process of network information flow, value flow, and human resource value and use value, forming network knowledge spillover effects led by digital libraries.

4.4.3 Significance of the Research

From the perspective of European and American countries that launched the Internet economy and computer-centered information technology, this knowledge spillover effect aligns with their global strategies. They leverage leading economic, technological, and knowledge advantages to penetrate developing countries and regions to obtain benefits generated by technology and knowledge, with digital library technology and resource output clearly subordinate to this strategy. From the endogenous growth theory perspective, developed countries possess advantages in digital technology and digital resource development, generating knowledge economy effects through knowledge product and network service output. The model reflects that capital flow always moves toward foreign developers and commercial digital libraries, while domestically, public digital library capital flows toward data developers and commercial digital libraries. Technology and knowledge exporters obtain economic benefits, utilizing knowledge's reusable characteristics to continuously generate endogenous growth. Notably, due to knowledge spillover effects, developing countries can also utilize learned technologies and knowledge for technological and knowledge innovation, thereby narrowing gaps with developed countries and achieving leapfrog development. Recognizing this point assists governments at all levels in macro decision-making and forecasting when developing various digital libraries.

5 Conclusion

In the basic model of digital library endogenous value and knowledge spillover effects, the author divides the digital library network system into three segments and seven modules, analyzing the relationship between its endogenous variables and knowledge spillover. The study finds that each segment and module maintains direct or indirect interactive relationships with other segments and modules—characterized by internal and external connections of capital flow, information flow, and technology flow; organic connections among human capital, endogenous growth, and knowledge spillover; and mutually promoting relationships of economic and social benefits between systems. This precisely demonstrates that the digital library network system is an organic whole growing within the global Internet, with knowledge spillover exhibiting global effects.

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

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