A Review of Research on Classification, Ownership Confirmation and Value Evaluation of Enterprise Digital Assets—— From the Perspective of Digital Asset Construction and Value Realization

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Abstract. In order to evaluate the value of digital assets accurately and effectively, this paper summarizes the previous studies, and makes a concrete analysis based on the statistics and valuation of digital assets. Through literature research, this paper systematically discusses the statistics and valuation of digital assets. Firstly, this paper analyzes the concepts of digital assets, data assets and digital currency, and puts forward the connotation of digital assets. Secondly, combined with the way of realizing the value of digital assets, this paper divides digital assets into three categories, and summarizes the attributes and characteristics of digital assets under different categories. Thirdly, it summarizes the research status of ownership confirmation of digital assets, sums up the previous evaluation of digital assets according to the classification of valuation methods, and puts forward that the evaluation of digital assets should be based on its classification. Finally, combined with the development trend of digital economy, the future research direction of digital asset statistics and accounting is prospected.

Keywords: Data Resource, Digital Asset, Data Value, Confirmation of Asset Appraisal Ownership

1 Introduction

In the era of big data, the rapid rise of digital technology revolution and the continuous development of the digital economy have made digital elements an important productive force. Improving the value evaluation methods of digital assets is becoming increasingly necessary and urgent, and has become an important issue that needs to be studied and solved urgently. This article starts from the perspective of studying the value realization methods of digital assets, and based on the study of the connotation, classification, and characteristics of digital assets, puts forward some preliminary understanding of the ownership confirmation and valuation issues of digital assets.

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2 Connotation of digital assets

Before discussing the concept of digital assets, first analyze and organize them with some similar concepts. There are three groups of concepts related to digital assets: digital assets, data assets, and digital currency. On the basis of conceptual analysis, analyze and explore the connotation, value realization methods, and classification of digital assets.

The term 'digital assets' was first proposed by Meyer [1] in 1996, and Neikerk (2006) [2] first defined digital assets as any text or media project formatted as binary source code that contains usage rights. Toygar (2013) [3] inherited and promoted this viewpoint, believing that digital assets are ownership of data stored in binary form in a computer or internet cloud. The above research indicates that one of the more recognized characteristics of digital assets is their existence in binary form. However, another group of scholars focuses on the asset nature of digital assets, emphasizing that it is a characteristic of digital assets that can bring expected economic benefits to enterprises. Wang Xiaoguang (2013) [4] defines it as a non monetary asset with potential economic value that is owned or controlled by an individual or institution, exists in the form of digital information, is held for sale in daily activities, or is in the production process.

The concept of 'data assets' emerged earlier, as early as 1974, Richard E. Peters (1974) [5] proposed the concept of' data assets', which he regarded as assets such as government bonds. At present, the academic community has discussed the connotation of "data assets" from different perspectives. In the 2019 Open Government Data Act, the United States defined data assets as a collection of data elements or datasets that can be combined from a legal perspective. Li Yaxiong et al. (2017) [6] defined data assets as quantifiable data-driven resources that can be processed by enterprises to achieve specific business goals and bring economic benefits to the enterprise, starting from the commercial essence of data assets. Shi Aixin et al. (2017) [7] classified data into structured and unstructured categories based on data classification. They believe that data resources that can bring economic benefits to institutions and individuals after collection, organization, screening, and analysis can be referred to as data assets. Qin Rongsheng (2020) [8] combines the IASB (2018) definition of assets, starting from the dimensions of data and assets, and defines them as current data resources that are controlled by enterprises due to past events and have the potential to generate economic benefits for the enterprise.

There is no unified conclusion on the definition of "digital currency" in existing literature. The academic community explores the connotation of "digital currency" from multiple perspectives such as payment methods, virtual currencies, and electronic currencies, focusing on the basic functions and legal attributes of currency. In 1982, David Chaum first proposed a theory related to digital currencies in his book "Blind Signature for Untraceable Payment Systems". In the "Digital Currency" report released by the Bank for International Settlements in 2015, digital currency was defined as an electronic form of currency, with its value stored in chip cards or personal computer hard drives, including central bank reserves, commercial bank deposits, etc., belonging to the broad definition of electronic currency. Cai Chang, Song Shuang, and Li Min all divided digital currency into sub categories of digital assets. Cai Chang et al. (2020) [9] believe that digital assets in a narrow sense are digital currencies; The broad definition of digital assets includes data generated by information systems, which exist in electronic form and are directly related to asset transactions (logistics, funds, information, commodity flows) and industry data. Song Shuang (2020) [10] classified digital assets into digital currencies, digital securities, digital commodities, and digital derivatives of the aforementioned products. Li Min (2020) [11] classified digital assets into digital currencies and digital tokens from the perspectives of payment and financing. Digital currency is a payment tool, such as Bitcoin, which has been accepted by large suppliers such as Microsoft to purchase goods and services; Digital tokens are a financing tool that, based on different transaction structures, carry different rights (such as usage rights or usufruct rights) and can be purchased by mainstream digital currencies, and can be transferred for profit in the secondary market.

In summary, it can be seen that the connotations of digital assets and data assets roughly converge, while digital currency belongs to the first two and is one of its special manifestations. Gao Wei (2016) [12] and Wang Hansheng (2019) [13] even equate "digital assets" with "data assets", defining them as data resources owned or controlled by enterprises and organizations that are expected to bring future economic benefits to them. Based on this, this article defines "digital assets" and "data assets" as the same concept, which refers to the real data resources that exist in the form of digital information, are controlled by the enterprise due to past events, and are expected to bring economic benefits to the enterprise. Our points are emphasized here. Firstly, the object emphasizes the digital form, which is the resource formed after meaningful data is aggregated to a certain scale; Secondly, it is expected to bring economic benefits to the enterprise, that is, increase its operating revenue or save operating costs; Once again, if the value of the data resource can be reliably measured, the value evaluation of digital assets can be completed, which is currently the most discussed topic; Finally, control by the enterprise due to past events refers to the ownership of the resource by the enterprise, or although the enterprise does not have ownership of the resource, the resource can be used by the enterprise, such as user information collected by the platform. We will further discuss this in the following text.

3 Value realization and classification of digital assets

3.1 The way to realize the value of digital assets

There are three basic ways to realize the value of enterprise digital assets as shown in Figure 1: firstly, digital financial assets with inherent value, which are currencies presented in digital form and can be electronically transferred, stored, or traded as payment methods, or digital securities can be traded and traded through digital platforms, (For example, QQ coins, Bitcoin, USTD, CBDC, digital warrants issued by Tencent); The second is that data itself can generate value, and the process of realizing the value of digital assets is the process of external transactions of data, which is common in some enterprises that mainly focus on data transactions(For example: data text, software, cloud computing services, artificial intelligence services, etc); The third is to use digital assets to indirectly empower businesses and realize value. The benefits brought by digital assets to enterprises are not only reflected in the traditional sense of increasing sales revenue, but also in improving the quality of internal management and helping enterprises establish competitive advantages in the industry(Such as: sold out rate, order flow, destination, number of registered members, repurchase rate, etc). [14]

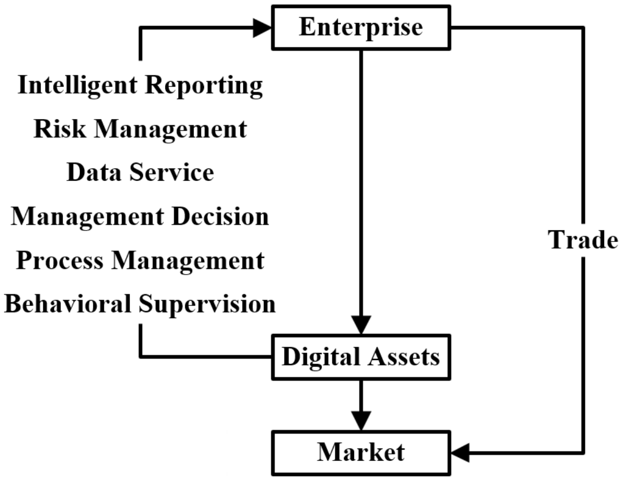

Fig. 1. Ways to realize the value of digital assets.

3.2 Classification of digital assets

There is still no unified definition in the academic community regarding the categories and types of digital assets. Scholars classify it into different categories from different perspectives.

Wang Fangfang [15] divided digital assets into development platforms, software, and software data in his legal definition and protection of digital assets. He believed that development platforms were original digital assets, and software was generated by attaching to the development platform. Other digital assets, such as video, audio, and data text, were generated by attaching to the software.

Starting from the fields of payment and financing, Li Min divides digital assets into digital currencies represented by Bitcoin and digital tokens represented by Ethereum.

Tan Mingjun (2021) [16] believes that digital assets are digital financial assets and categorizes them as shown in Table 1:

Table 1. Types and Characteristics Differences of Digital Financial Assets

Category / Characteristic differences	digital currency	virtual currency	Cryptocurrency	Traditional digital financial assets
Issuer	central bank	network platform	There is no specialized subject and the algorithm is generated based on rules.	Issued by an agency authorised or licensed by the government

typical representatives	Central Bank digital currency	Q coins, game coins, platform internal points, etc	Bitcoin, Ethernet, etc	Digital warrants, stock index futures, etc.
Issuance method	centralization	centralization	Deconcentration	centralization
Number of issues	Adjusted by the central bank based on macroeconomic and monetary policies	It is up to the platform to decide.	Constant quantity	The decision is subject to the approval of the underlying asset value by an authorised or licensed trading entity.
money value	Equal to French currency	If it is not equal to French currency, it can be purchased through French currency.	If it is not equal to the French currency, it can be traded through the French currency.	If it is not equal to the French currency, it can be traded through the French currency.
Credit guarantee	National credit	Corporate credit	Network credit	Government credit
serviceable range	Equal to French currency	Inside the platform	Within any network entity that supports encrypted money	Within an authorised or licensed trading establishment
Mode of circulation	Equal to French currency	One way; Fiat can purchase virtual currency, which is not convertible into fiat	Two-way; French currency can be purchased in encrypted currency, which can also be converted into French currency.	Two-way; The asset can be purchased or sold in French currency.
Transaction security	polar altitude	Extremely low	lower	higher

The author believes that from the definition of digital assets, any real data resources that exist in the form of digital information, are controlled by enterprises due to past events, and are expected to bring economic benefits to the enterprise belong to the category of digital assets. Therefore, whether it is digital currency, information products, or software, they are all data resources that meet the conditions for asset recognition and should be classified as digital assets, After organizing and analyzing previous research results, the author reclassifies digital assets according to their value realization methods as follows:

1. Data empowers business within the enterprise

The raw data generated from transaction and management activities that have been collected, processed, and organized become high-quality data with reference value for enterprise business decision-making and operational management. Although this type of digital asset initially has asset attributes, it cannot create value for the enterprise alone and still needs to be related to the original economic business. It must rely on the business as the way to achieve value, that is, through the integration and innovation of digital assets at the business end, to create more value for the enterprise.

This article provides an appropriate summary of the characteristics of digital assets that empower business within the enterprise, including dynamism, business attachment, iterative accumulation, and value uncertainty.

Firstly, dynamism. Data is a highly liquid and timely asset. For example, consumer consumption records emphasize real-time data, which loses its accuracy over a certain period of time because consumer consumption needs change over time. Therefore, digital assets need to be dynamically maintained to maintain their timeliness. Only by continuously accumulating and updating data can they meet the needs of diversified use. The storage, maintenance, and management of digital assets require high costs in order to maintain their value.

Secondly, business attachment. Data itself does not generate value, but enterprises can improve their existing products and services based on data, prompting them to reduce costs and increase profits. By collecting, analyzing, and organizing data, enterprises can apply it to their own production and operation decisions, improve business processes, and thereby improve the efficiency of products and services. [17] For example, using digital assets to organize intelligent production, accurately positioning customer value, and optimizing financial management.

Thirdly, iterative accumulation. As the frequency of transactions and usage increases, it continuously differentiates, integrates, and accumulates iteratively. The change in user level brings about an increase in accumulation speed. For example, an internet platform that everyone uses will record a large amount of user login information, as well as their browsing and consumption behavior. This huge amount of data will continue to grow and grow based on the development of the platform. These data provide personalized recommendation algorithms for platform websites, assist in customer demand analysis, and continuously differentiate and integrate while meeting social needs and being repeatedly used. They can also create valuable digital assets, making digital asset investment have the nature of increasing returns to scale.

Fourth: Value uncertainty. Unlike traditional assets, where future returns can be predicted based on fixed production efficiency and costs, the value of digital assets can vary greatly depending on specific application scenarios, and there is no set of income measurement methods applicable to all scenarios. Moreover, such assets themselves have no value and only have usable value after data processing. These factors cannot be measured by specific indicators, so the value of digital assets has great uncertainty.

From an internal perspective of the enterprise, digital assets can be utilized to empower strategic layout, production and operation, thereby improving the efficiency of business decision-making and enhancing the efficiency of enterprise management. From an external perspective, most companies that take the lead in effectively utilizing digital assets can control the industry ecosystem and gain an advantage in industry competition. Having advanced data awareness and a complete digital system, integrating industry data, connecting upstream and downstream of the industry chain, can become a core enterprise that partners rely on.

2. Data generates value in external transactions

(1) Digital intangible assets

Valuable digital information resources such as text, images, audio and video, as well as royalties, copyrights, patents, etc.

(2) Digital conventional services or products

Digital conventional services or products are digital forms of services and products, published by companies or individuals on the blockchain to represent their products or services. For example, computer software, cloud storage, and other products or services that can be digitized and transmitted through computer networks.

Digital conventional services or products have the following characteristics: firstly, economies of scale. When the scale of digital services or products is small, it will not bring good economic effects. In the early stage, a large amount of research and development and investment costs need to be invested. When the platform product reaches a certain scale and develops rapidly, the investment cost in the later stage will decrease. Therefore, this type of digital asset has the characteristics of low variable cost and high fixed cost in high scale economy; [18] The second is indestructibility. Due to the fact that digital assets are stored in the form of data and have no physical existence, their use does not depreciate. Even if the storage carrier is physically damaged, as long as digital assets have backup and storage, they will not be lost. This characteristic is similar to other traditional intangible assets.

The construction process of digital conventional services or products is shown in Figure 2:

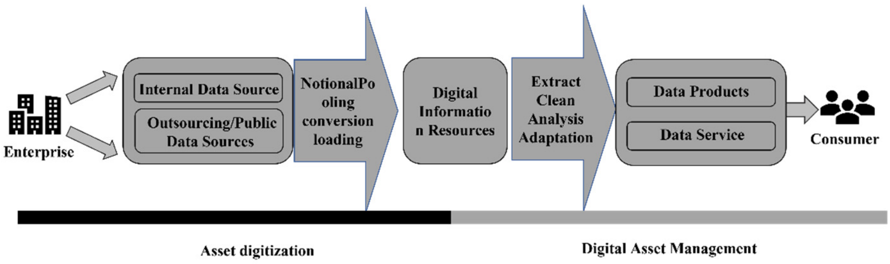

Fig. 2. Construction process of conventional services or products

Digital products and services are supported by digital platforms, and there are generally five types of profit models as shown in Table 2:

Table 2. Profit model of conventional services or products

classify	app; application		Key profit model
Information-oriented class	Search navigation	Baidu search, hao123	Internet advertising, technical support, copyright fees
	netnews	Sina.com, Today's Headline	
Business transactions	B2B	Alibaba, Universal Business Network	Online advertising, platform profitability, sales of physical

	B2C	Taobao, JD.COM Mall	products and services, sales of virtual products and services
	O2O	US Mission Delivery, Shenzhou Special Vehicle	
	C2C	Sinecure Fish, Aibiying, Tencent Pai	
Internet finance	online investment	Ant financial	Sales of virtual products and services, platform earnings, accrued interest income
	Online payment	Alipay	
Culture and entertainment	IM	Wechat, Tencent QQ	Online advertising, sales of virtual products and services
	Social networking	Sina Weibo, jiayuan	
	amusement	QQ music, letv	Online advertising, sales of virtual products and services, copyright fees, sales of physical products and services
Industry services	online education	Netease Open Class	Platform profitability, sales of virtual products and services
	personnel recruitment	nasdaq:jobs	

3. Data itself has value

(1) Digital currency

Digital currency exists in the form of electronic data, representing the ownership and value of underlying assets. As shown in Table 3, digital currencies are further divided into legal digital currencies, virtual currencies, and cryptocurrencies. Legal digital currency is a currency equivalent to fiat currency issued by the central bank and guaranteed by national credit. Virtual currency refers to a currency that can purchase goods and services within a specific community in the virtual space of an online platform, and has the function of a transaction medium and accounting unit, such as Tencent QQ coin, game currency, etc. Cryptocurrency is a digital currency based on cryptography and different mechanism algorithms, with decentralized characteristics, such as Bitcoin, Ethereum, Litecoin, etc.

Table 3. Classification and characteristics of digital currency

Category / characteristic	Statutory digital currency	virtual currency	Cryptocurrency
Issuer	Government (central bank)	platform	private
nature	Distribution centralization	Distribution centralization	Deconcentration
Code properties	keep secret	keep secret	open-source
quantity	uncertain	uncertain	sure

Is it anti-inflation	no	no	yes
area of application	Instead of cash, a wide range	Platform specific	Limited scope

(2) Digitizing traditional financial assets

It is a digital form of conventional financial assets. Digital warrants, stock index futures, and other financial services issued by government authorized or licensed institutions, through the use of new generation information technology, connect finance with digital technology, forming new organizations and models of financial services. Its characteristics have two aspects. Firstly, it is data-driven, based on data and driven by technology. It widely applies a three-dimensional interaction architecture, deeply explores customer value, and accelerates the flow of funds and industries through information and technology flows. The second is the refinement and networking of financial division of labor, which no longer focuses on a single institution and assumes all risks in the financial chain.[18]

4. Confirmation of digital asset ownership

Clarifying the ownership of digital assets is the primary issue that should be addressed in data assetization. It is the foundation for the application and protection of data rights, and also a necessary prerequisite for recognizing data as digital assets.

At present, there is no consensus in the academic community on the discussion of data ownership, among which the "new personality rights theory", "intellectual property theory", "trade secrets theory", and "data ownership theory" are the most representative.

Among them, the new personality rights theory only focuses on personal data, the trade secret theory only focuses on commercial information data, and the intellectual property theory does not consider data that cannot form databases and datasets. In contrast, the data ownership theory is more suitable for the development of big data. Scholars from developed countries generally pay attention to data property rights, especially data ownership. Loshin believes that data ownership refers to the ownership and responsibility of information. Ownership includes rights and control, and control of information includes the ability to access, create, modify, package, derive benefits, trade or delete data, as well as the right to transfer data access to others. [19] and Tan Mingjun (2021) suggest diluting the ownership of digital assets and focusing on defining them from the perspective of usage rights.

Ding Xiaodong (2019) believes that protecting personal data rights and corporate data rights must adopt a scenario based protection approach. In specific scenarios, determine the nature and type of data, and determine the data rights and interests of relevant entities based on the reasonable expectations of all parties in the scenario. [20]

Wang Yuan (2017) classified data ownership confirmation methods into four categories based on data sources. The right to original data belongs to the creator of the original data, and others can only enjoy restricted data use rights within the agreed scope of the original data owner, and under the premise of making commitments to privacy, security, scope of use, consideration, and purpose. The processor of secondary data has property rights over the data, which can be manifested as copyright, neighboring rights, and ownership according to different circumstances. The ownership of national data belongs to the state, management rights belong to local governments, and development is carried out by enterprises. Public data is ownerless and should be shared by all citizens. [21]

The core of defining the ownership of digital assets is to clarify the relationship between data providers, data collectors, third-party platforms, and data demanders, and to determine it based on relevant laws, regulations, and agreements among all parties.

5. Value Evaluation Methods

The four evaluation methods for tangible assets are now relatively mature, mainly including the present value of income method, replacement cost method, current market price method, and liquidation price method. The evaluation methods for intangible assets are also becoming increasingly perfect, mainly including market method, cost method, and income method. Due to the characteristics of non entity and uncertainty, digital assets can be compared to intangible assets for value evaluation. The author compares three traditional evaluation methods for intangible assets, as shown in Table 4:

Table 4. Comparison and advantages and disadvantages of market method, cost method and income method

	Market method	Cost method	income approach
definition	Refers to the asset evaluation method that searches for the recent transaction price of the same or similar assets in the current market environment, takes the evaluated digital assets with reference value as the reference coordinates, makes direct or indirect comparison, analyzes the similarities and differences between the evaluated assets and the recently sold similar assets, and thus determines the value of the evaluated digital assets.	Cost method is divided into two kinds, one is the historical cost method, the other is the replacement cost method, the cost method mentioned in the valuation of digital assets usually refers to the latter. Replacement cost method refers to the method of determining the value of the evaluated assets based on the actual replacement full price of the evaluated digital assets, net of loss or depreciation.	By measuring the expected revenue that the digital assets can bring to the enterprise in the future, the value of the future revenue of the evaluated enterprise is discounted to a specified date by a specific discount rate, so as to evaluate the value of the target digital assets and reflect the additional profitability of the digital assets.
Applicable premise	The appraised asset has an open and active capital market for transactions, which is available by reference to information such as the asset and its indicators of comparison with the appraised asset.	The assessed asset is in continuing use or is assumed to be in use; The asset itself is replicable and reproducible; The asset has available historical materials; Assets become obsolete and depreciated over time, which is not applicable if the value increases inversely.	The indefinite return and risk of the asset being assessed are predictable and measurable in currency; The expected profit-making life of the assets assessed is predictable.

advantage	1. Under the background of digital economy, the digital asset market is becoming more and more active, the number of transaction assets available for reference is increasing, and the feasibility is becoming higher and higher. 2. The market method can more objectively reflect the current market conditions of the assets, and the assessment value can better reflect the current market price.	1. Based on cost structure, easy to understand. 2. The calculation is based on summation and simple.	1. Reflects the economic value of digital assets, intuitive and easy to understand. 2. It is widely used and can be understood and accepted by most scholars and all parties in the asset appraisal business.
disadvantage	1. Digital assets are various and their value is uncertain. The value changes constantly with the change of application scenarios. The values of the same digital assets reflected in different transactions or application scenarios may differ significantly. 2. It is difficult to guarantee the openness and transparency of the pricing of specific transactions. 3. The value of digital assets is affected by various factors, and the workload for quantifying the differences is large.	1. The value that the digital assets can bring to the enterprise far exceeds the current cost of rebuilding the digital assets, and the characteristics that the digital assets may increase in value in the application process are not considered, which results in the value of the digital assets being greatly underestimated. 2. The corresponding costs are not easy to distinguish. Some digital assets are derivative products in production and operation, and the data are constantly changing. The corresponding direct costs cannot be determined, and the allocation of indirect costs is not easy to estimate. 3. It is not easy to estimate the depreciation factors of digital assets. The factors that cause the depreciation of various types of digital assets are different.	In most cases, the use and function of digital assets is to help businesses make decisions. For this purpose, the revenue that digital assets bring to the enterprise is intertwined with the products of the enterprise, which is difficult to separate. However, when the revenue method is used to evaluate digital assets, the digital assets must be calculated as an independent individual, which makes it difficult to evaluate the value of digital assets using the revenue method.

5.1 Value Evaluation of Digital Assets Based on Market Approach

Li Yonghong and Zhang Shuwen believe that based on the information lifecycle theory, the value of digital assets can only be reflected in the exchange process, so the market approach is applied as the evaluation basis. From the perspectives of data quantity, quality, and data analysis ability, the influencing factors of digital asset value evaluation are determined. The weight of each influencing factor is calculated using the Analytic Hierarchy Process. The grey correlation method is used to quantify each influencing factor, calculate the correlation coefficient, and then calculate the correlation degree. Based on this, comparable digital assets are selected, and a value evaluation model as shown in Figure 3 is constructed [22]:

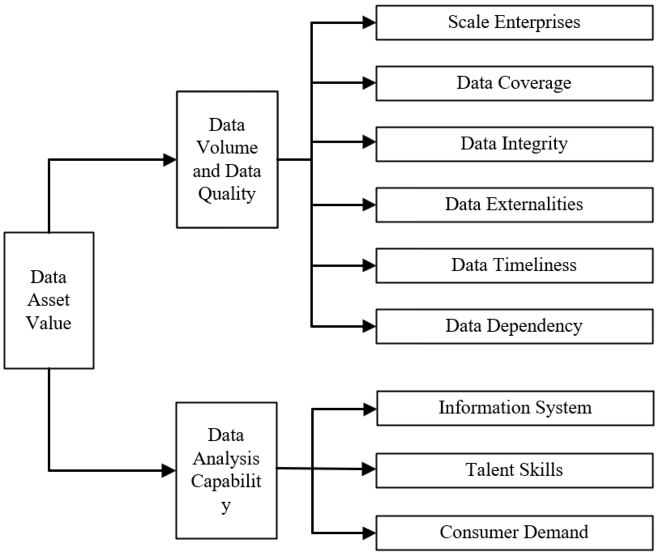

Fig. 3. Analytic hierarchy process model

Liu Qi et al. used the market approach to quantitatively evaluate the value of digital assets by quantifying the differences between them. Establish six indicators as shown in Figure 4 to basically clarify the value differences brought about by technological progress. Secondly, the Analytic Hierarchy Process is applied to compare each indicator with the other five indicators in pairs to determine the importance of the indicator relative to another indicator in the same group, in order to determine the weight of each indicator. Finally, the technical correction coefficient is comprehensively determined, and its value is adjusted from the aspects of acquisition cost, technology, value density, and data capacity differences of digital assets. [23]

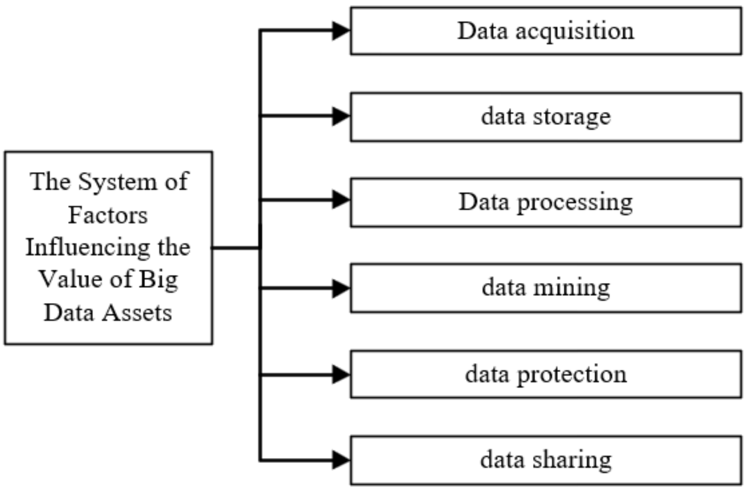

Fig. 4. The System of Factors Affecting the Value of Big Data Assets

Song Jiekun and others constructed the indicator system shown in Table 5 based on the basic process of digital asset formation and management, and established a digital asset value evaluation indicator system consisting of 11 indicators including data cost, apparent value, and service value. Use the AHP method to calculate the weights of each indicator, and apply intuitive fuzzy entropy for objective weighting. Finally, use a single evaluation model such as Borde for calculation, and substitute the results into the combined evaluation model for consistency testing. [24]

Table 5. EDAV evaluation index system

Level 1 indicators	Secondary indicators	Meaning of secondary indicators
Data cost	Carrier costc	Construction and renovation costs incurred in creating data carriers such as various business data systems and converged data systems (e.g. data warehouses, data marts)
	Outsourcing cost C2	Costs of purchasing data sources from outside the enterprise
	Operation cost C3	Costs for daily data collection, cleaning, loading, storage, dynamic monitoring and integration, and security maintenance, fault detection, etc.
	Service costsc	Costs incurred in data calculation, analysis, mining, delivery of goods, etc. to meet internal business scenario requirements and customer customization requirements
Apparent value	Scale of datac	The amount of data owned and controlled by the enterprise
	Data completeness c	Delivery data supports internal decision-making within the business area and completeness of coverage of external services
	Data plausibility c	Accuracy and reasonableness of delivery data
Service value	Revenue from servicesc	Revenue from delivery of data products to external customers
	External customer satisfactionc	Satisfaction degree of external customers on the quality of data delivery products, delivery time limit, etc.
	Decision support contribution C10	The level of contribution that a data deliverable or data source makes to the enterprise's own strategic, operational, and other decision support
	Internal application satisfaction C11	Satisfaction of departments within the enterprise with the data deliverables or data sources in terms of scale, quality, timeliness, etc.

(1) Value Evaluation of Digital Assets Based on Cost Method

Lin and Wu believe that the value of data assets is the sum of the cost of data assets and the application value of data assets. They evaluate the cost of data assets from three perspectives: acquisition cost, operation cost, and maintenance cost. The main evaluation indicators for data asset application are data asset type, application time, application object, and application effect. Therefore, a calculation model for data asset value is established, And use the YAAHP analysis software method to calculate the weights of each indicator. [25]

Zhang Yongmei and Mu Wenjuan decided to choose the cost method for intangible asset valuation by comparing the differences in three commonly used methods, and established a financial asset valuation model. The expression for the evaluation value of financial data assets can be found in formula (1). When calculating the replacement cost, the multiplication coefficient method is used, as shown in formula (2). The meanings of each symbol in the formula [26] are shown in Table 6:

$$PV = P \times (1-R) \times r_e + t \tag{1}$$

$$P = \frac{(C+V)(1-R)}{1-\beta_2} + \alpha \sum_{t=1}^{n} R_t (1+r)^{-t} \tag{2}$$

Using the risk return rate model to calculate the discount rate, the calculation formula is as follows:

$$r = r_r + \beta(r_m - r_f) + \alpha \tag{3}$$

Table 6. Meaning of each symbol

symbol	meaning	remarks
PV	Financial data asset valuation	
re	Transfer cost allocation rate	Average annual revenue from right-of-use transfer/total cost of research and development
T	Opportunity cost of transfer	0 in financial data asset assessment
P	Replacement cost of financial data assets	
C	Materialized Labor Consumption of Research and Development Data Financial Assets	Raw materials, electricity, fuel, etc. used in the research and development process
V	Live labour costs of developing financial data assets	Remuneration of research and development personnel in the research and development process
β1	Double coefficient of creative work of scientific researchers	The general value of high-tech information technology companies is 1.5.
β2	Average risk coefficient of scientific research	Take the equivalent of 0.35 in Hi-Tech Information Technology Company
R	Financial data asset depreciation rate	Useful life/total useful life
α	Financial data asset contribution rate	Draw lessons from the industry value of 0.9
Rt	New net income per year	New financial data asset income per year
r	Applicable discount rate	Calculated from the risk return rate model
n	Useful lives of financial data assets	According to the relevant provisions of high and new technology, the total fixed number of year is 20 years.

Zhang Zhigang et al. analyzed the composition and main influencing factors of digital assets, constructed the cost and application indicator evaluation system shown in Figure 5 using the AHP method, and calculated the weight of evaluation indicators using the YAAHP hierarchical analysis software. Finally, the digital asset value evaluation calculation model was applied: digital asset value=digital asset cost score+digital asset application evaluation score, and the digital asset value was obtained [27]. The specific operation steps are shown in Figure 6:

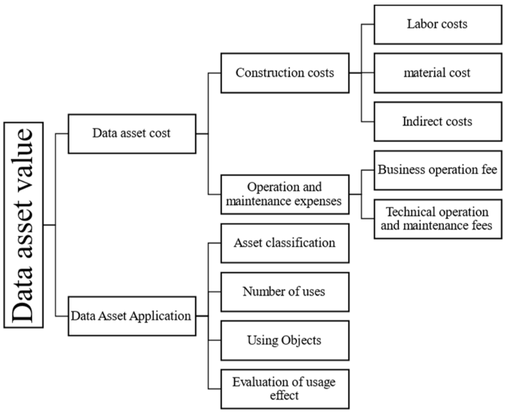

Fig. 5. Composition of data value and main influencing factors

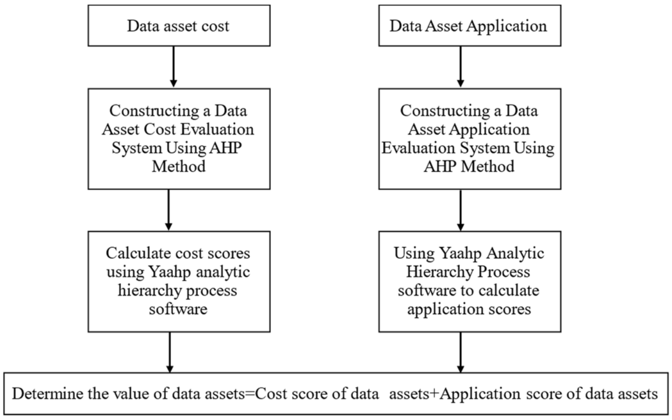

Fig. 6. Operation steps of data asset value evaluation

(2) Value Evaluation of Digital Assets Based on Income Method

In digital asset evaluation, the income method mainly includes excess income method, incremental income method, license fee saving method, income sharing method, green space method, etc. The incremental income method mainly determines the value of digital assets by comparing the income difference of enterprises with or without evaluated digital assets; The excess return method first uses the residual method to separate the excess return attributable to the data asset from the overall return, and then partially discounts the excess return; The license fee saving method determines the return on digital assets based on the savings in license fees; The income sharing method believes that income can be distributed among assets at a certain sharing rate; The excess income method is the most core model in the income method, while other models such as the license fee saving method, incremental income method, and green space method are all variants of the excess income method [28-30]. In the existing literature, the income method basically uses the excess income method.

Chen Fang and others comprehensively considered the characteristics of digital assets and applied the multi period excess return method to establish a digital asset value evaluation model, and calculated the discount rate of digital assets. Firstly, the weighted average cost of capital model is used to calculate the overall investment return of the enterprise. Then, the rate of return splitting method is used to deduct fixed assets and current assets. Finally, the discount rate of digital assets is peeled off, and the value of digital assets of the digital transformation enterprise is evaluated. [31]

Yuan Zeming and Zhang Yong'an also used the excess return method to first calculate the overall excess return of the enterprise, and believed that the excess return was created by intangible assets. Then, intangible assets were classified, and the past digital asset sharing rate was calculated using the Analytic Hierarchy Process to calculate their return amount. Based on this, the GM (1,1) model was applied to predict the future excess return of the enterprise, Finally, choose the appropriate discount rate and return period to discount future excess returns, which is the value of digital assets. [32]

Liu Huiping et al. constructed an improved multi-period excess return model to evaluate corporate digital assets, improved the multi-period excess return method using the Pear curve and GM (1,1) grey prediction model, and selected the digital assets of IoT industry giant Hikvision as the evaluation object to test the applicability of the valuation model.

(3) Value evaluation of digital assets based on other methods

Huang Le and others innovatively introduced parameters such as platform activity coefficient using market method, cost method, and income method to construct a platform based data asset value evaluation model as shown in Figure 7, and verified the model through empirical cases. [33]

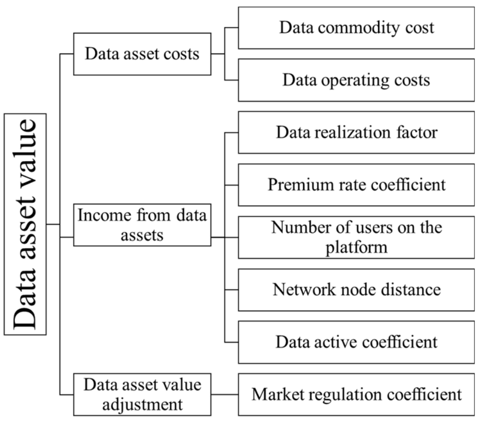

Fig. 7. Composition of data value and main influencing factors

Other scholars believe that traditional market methods, cost methods, and income methods have their own advantages and disadvantages, and the evaluation results are inaccurate and not suitable for digital asset value evaluation. They try to find a breakthrough from non-traditional models in the fields of economics, management, and computer science to evaluate the value of digital assets.

Li Bingxiang and Ren Hanxiao conducted in-depth research on the characteristics of digital assets, improved the B-S model, and evaluated the value of digital assets based on this. They constructed a digital asset value evaluation model from four aspects: the number of users and clicks on the platform, the value generated by the application of digital asset usage rights, the excess returns generated by the transfer of data asset ownership, and the impact of risk policies and moral factors on quantitative or even qualitative changes in data. [34]

Zhao Li and Li Jie first used the replacement cost method and income present value method to determine the upper and lower limits of the theoretical price range of digital assets, and constructed a three-stage bargaining model based on the price range, using feedback pricing strategies to promote the rationalization of big data asset pricing. [35]

According to the requirements of digital asset valuation under practical conditions, Zuo Wenjin and others organically combined asset valuation theory with game theory models to design digital asset valuation methods and construct an optimization system for digital asset valuation methods. [36]

Xiong Li and Liu Mingming analyzed the restrictive factors of data pricing, such as unclear property rights positioning, non-standard data formats, network externalities of data products, and uncertainty of transaction parties. Starting from five dimensions of price value, functional value, competitive value, emotional value, and social value, they established a data product pricing mechanism based on customer perceived value as shown in Table 7. [37]

Table 7. Index System of Customer Perceived Value in Data Transaction

Target level	Dimensions (Level 1 Indicator)	Drivers (secondary indicators)	Factor weight
Customer Perceived Value Pricing	Emotional value	Environmental properties	0.32784
		Service properties	
		personal partiality	
	Social value	Enterprise performance	0.24982
		Data integrity	
	Functional value	Timeliness of data	0.24700
		Data depth	
		Data coverage	
		time span	
	Price value	Consolidated cost	0.17534

Wang Jing and Wang Juan combined the actual operational characteristics of internet finance enterprises, combined with the current situation of data assets, and applied the AHP method to construct an evaluation index system for the influencing factors of data assets in internet finance enterprises. They also combined the B-S theoretical model to construct an evaluation index system for their data assets from five aspects: target data assets, real-time data asset floating rate, complete life cycle, fixed return rate, and existing data assets, Obtained the relationship between the internal influencing factors of its underlying data assets. [38]

Zhou Qin and Wei Yongchang studied the value of digital assets in the e-commerce industry from the perspective of asset evaluation. Firstly, they determined the value of intangible assets, which is the difference between the market value and book value of the enterprise. Then, they divided intangible assets into domain names, management levels, customer networks, human capital, and data assets. Then, they innovatively combined Monte Carlo simulation with Analytic Hierarchy Process to calculate the value of data assets in intangible assets. [39]

Yuncheng Shen et al. analyzed and compared existing data pricing models and strategies, and proposed a big data pricing model based on tuple granularity. This model analyzes and studies the impact of changes in data attributes, information entropy, weight values, data reference indices, costs, and other factors on value, in order to perform positive rating and reverse pricing on big data. The model can dynamically adjust according to the changes in the above parameters. [40]

Haifei Yu et al. considered data quality and data version control strategies and proposed a two-level mathematical programming model to solve data pricing problems. The model variables are shown in Table 8. Data products and data related services differ from information products or services in terms of quality assessment methods. This model considers two aspects of data quality: (1) its multidimensional nature; (2) The interaction between dimensions, and the application of genetic algorithms to solve the model, in order to achieve maximum profit for data platform owners and maximum utility for consumers.[41]

Table 8. Model variable

Variable	Variable Descriptioni
i	The number of data-product versions, i = 1,2,. . . ,M
j	The number of data consumers,j = 1,2,.. . ,N
k	The number of data-quality dimensions, k = 1,2,.. . ,K
c_i^L	The linear cost of data product i
c_i^I	The integrated cost of data product i
p_i	The price of data product i
c	The parameter of the cost function
q_{ik}	The quality level of data product i in quality dimension k
q_{ik}^L	The linear quality of data product i with quality dimension k
q_{ik}^I	The integrated quality of data product i with quality dimension k
q_{jk}^R	The reservation quality of consumer j in quality dimension k
q_{jk}^S	The saturation quality of consumer j in quality dimension k
θ_{jk}	The quality preference of consumer j in quality dimension k
w_{ijk}	The willingness to pay of consumer j for data product i in qualitydimension k
w_{ij}	The willingness to pay of consumer j for data product i
w_{ijk}^L	The linear willingness to pay of consumer j for data product i withquality dimension k
w_{ijk}^I	The integrated willingness to pay of consumer j for data product iwith quality dimension k

u_{ij}	The utility of consumer j for data product i
x_{ij}	The purchasing decision of consumer j for data product i, xij= 0 or1
y_i	The production decision of the data platform owner for dataproduct i, yi = 0 or 1

6 Conclusion

This article systematically explores the statistical and valuation issues of digital assets. Firstly, by analyzing the concepts of digital assets, data assets, and digital currency, we believe that digital assets and data assets tend to converge, while digital currency belongs to the first two. Based on this, we propose the connotation of digital assets: existing in the form of digital information, controlled by enterprises due to past events, And realistic data resources that are expected to bring economic benefits to the enterprise. Secondly, based on the value realization methods of digital assets, this article divides them into digital assets that empower business within the enterprise, digital assets that generate value in external transactions, and digital assets that have value in their own data. It also summarizes the attributes and characteristics of digital assets under different classifications. Once again, the current research status of the ownership confirmation of digital assets is summarized, and the previous classification of digital asset value evaluation based on valuation methods is summarized. It is proposed that digital asset value evaluation should be conducted on the basis of its classification. Finally, based on the development trend of the digital economy, the future research directions of digital asset statistics and accounting are prospected.

The existing evaluation methods and models are unable to achieve accurate evaluation of the value of data assets. Different valuation methods have their own advantages, disadvantages, and limitations. The author believes that different types of digital assets should adopt different valuation methods, combining the characteristics of each classification to comprehensively use market method, cost method, income method, etc.

The income method cannot be applied to digital assets that empower businesses. Cost method and market method can be comprehensively applied. When establishing an indicator system, data quality, data cost, and service value should be mainly considered. Data quality should be considered from the perspectives of construction cost and operation and maintenance cost, while data cost should focus on timeliness, accuracy, completeness, and data scale, Service value should focus on aspects such as decision support contribution and internal application satisfaction.

Secondly, internet enterprises primarily engaged in digital intangible assets, digital conventional services, and products can use the income method to establish a multi-period excess return model based on the residual method to evaluate the value of digital assets.

Thirdly, for virtual currencies and cryptocurrencies, the value refers to their fair value. If there is an active market, the fair value is determined based on the quoted prices in the active market. If there is no active market, the market method should be used to compare trading financial assets, referring to the prices used in market transactions by parties who are familiar with the situation and willing to trade, and referring to the current fair value of other digital currencies that are essentially the same The discounted cash flow method and option pricing model are used for valuation. The value of digital traditional financial assets is determined by referring to the corresponding category of traditional financial assets, such as debt investments priced at amortized cost, other debt investments, other equity instrument investments, and transactional financial assets priced at their fair value.

Due to space limitations, there was no in-depth discussion on the accounting and information presentation of digital assets. Today, with the rapid development of the digital economy, the value evaluation of digital assets has become an important issue that needs to be studied and solved urgently. The author believes that future research can be carried out continuously and systematically from the following three aspects:

Firstly, in terms of confirming the ownership of digital assets. Subsequent research should build a ownership system and legal system for digital asset protection based on the separation of ownership and use rights of digital assets, based on the protection of user privacy and the rational utilization of resources.

Secondly, in terms of evaluating the value of digital assets. Firstly, standardize and refine the relevant policies and industry standards for digital asset value evaluation, and develop clear and detailed reference guidelines. Secondly, optimize and improve existing research methods and expand research on evaluation methods for different evaluation objects in different fields. Thirdly, promote the practical application research of existing evaluation methods. In the evaluation process, based on the combination of econometric models and asset evaluation methods, practical analysis should be conducted according to their application scenarios, and multiple evaluation methods should be integrated to establish a standardized evaluation method system suitable for different categories.

Finally, in terms of digital asset accounting and information presentation. Improve the recognition conditions, subject settings, initial recognition value basis, basis for subsequent measurement, and relevant accounting standards for incorporating digital assets into the accounting system.

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