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Research article

Digital trade exports, production networks, and economic growth

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Abstract: Digital trade exports generate final demand for domestic production, and through intersectoral input-output linkages, induce multiple rounds of intermediate input demand that contribute to domestic value-added. However, researchers have given insufficient attention to the value-added effect driven by digital trade exports via production networks, making it difficult to fully elucidate their value creation process. To address this gap, we combine the 2023 input-output table with multiple data sources, including *Custom Trade Statistics* and the *China Economic Census*, to compile a digital economy input-output table that distinguishes digital trade from traditional trade. Second, we construct a digital trade export driven model to quantify the value-added effects of digital trade exports, and decompose them into direct and indirect value-added effects. Finally, we further construct a production network for digital trade exports, identify its core sectors, and employ structural path analysis to trace the paths through which digital trade exports generate value added. The findings indicate that (1) In 2023, the value-added effects of digital trade exports exhibit significant indirect transmission characteristics, with the indirect value-added effect being approximately 2.3 times that of the direct value-added effect. (2) The core hub sectors possess strong bidirectional connectivity, and serve as pivotal nodes in the production network. (3) The core paths through which digital trade exports generate value added involve input linkages among digital manufacturing sectors and linkages from producer services to digital service sectors. By clarifying how production network linkages transmit the value-added effects of digital trade exports, this study provides a theoretical basis and policy insights for the development of digital trade.

Keywords: digital trade exports; production networks; value-added effects; demand-driven model; structural path analysis

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1. Introduction

The rapid growth of digital trade is reshaping the international division of labor and driving economic growth. Distinct from traditional trade, digital trade, as a new form of trade, is underpinned by digital technologies, data factor, and platform-based organization. It is characterized by low transaction costs, high matching efficiency, and cross-spatial resource allocation. Digital trade not only transforms trade ways and product forms, but also alters the link between international demand and the domestic production system. As digital technologies continue to permeate economic activities, digital trade exports have gradually become a key driver for expanding external demand, optimizing export structures, and enhancing industrial competitiveness. The final demand generated by digital trade exports creates direct demand for exporting sectors and spreads through the domestic production system via intersectoral input-output linkages, thereby stimulating production and demand for intermediate inputs in related sectors and generating domestic value-added across rounds of production. Particularly against the backdrop of increasingly complex industrial linkages, how digital trade exports propagate through production networks, what scale of direct and indirect value-added they generate, and what roles different sectors play in this process have become central questions for understanding the economic impacts of digital trade exports. Consequently, identifying the value-added effects of digital trade exports, clarifying the roles of various sectors within these production networks, and revealing the structural characteristics of transmission through the networks will help further elucidate the connections between digital trade exports and domestic production systems.

The final external demand generated by digital trade exports can be transmitted to the domestic production system through intersectoral input-output linkages, giving rise to multiple rounds of intermediate input demand, and contributing to value added. On the one hand, growing demand for digital trade exports expands production in exporting sectors and drives the development of upstream digital infrastructure, electronic equipment, and producer services through the demand for intermediate inputs. On the other hand, the digital technology products and services required for production in digital trade exporting sectors can also enter the production processes of other sectors through intersectoral input linkages, thereby creating cross-sectoral demand transmission. For example, growing demand in digital trade export sectors for intermediate inputs, such as network equipment, electronic components, and information services stimulates production in related sectors through input-output linkages. Moreover, digital platforms and digital service sectors, as providers of intermediate inputs, will further generate multi-round demands for intermediate inputs when their goods and services are utilized by other industries. Consequently, the value-added effect of digital trade exports depends not only on the scale of digital trade export, but also on the degree of input interdependence between digital trade exporting sectors and other sectors, as well as on the structural positions of sectors within the production network (Zhang and Zhou, 2021).

Production network theory provides an important analytical perspective for understanding the value-added effects of digital trade exports. Production network is a complex economic system formed by the input-output relationships among economic agents. Its core characteristic lies in how changes in one sector propagate along the upstream and downstream links of the industrial chain, generating amplification effects through the network structure (Guo, 2025). Acemoglu and Azar (2020) argued

that production networks are not merely forms of organizing economic activities, but also an important analytical framework for understanding intersectoral economic linkages and the transmission of shocks. Due to the intermediate input dependencies among sectors, an expansion in final demand for one sector can impact related sectors through input-output relationships, thereby triggering multiple rounds of demand transmission. Consequently, examining only the direct value-added generated by digital trade export sectors, while ignoring the indirect effects transmitted through production network, cannot fully capture the value-added effects of digital trade export.

Researchers have primarily examined the impact of digital trade on corporate performance, resource allocation, and production activities from a micro perspective. However, little attention has been given to the value-added effects of digital trade exports. Moreover, researchers have focused on the direct effects of digital trade on related economic activities, while lacking a systematic analysis of the indirect effects. The value-added effects of digital trade exports not only depend on the scale of export demand, but also on the extent of transmission through the production network and the degree of intersectoral input linkages. Therefore, constructing a production network for digital trade exports and identifying core sectors and key paths within this network can help elucidate how shocks to digital trade export demand propagate through the domestic production system.

In this paper, we focus on digital trade exports at the sector level. Utilizing the *2023 Input-Output Table* and *Statistical Classification of the Digital Economy and Its Core Industries (2021)*, together with multiple data sources, including *customs trade statistics* and the *China Economic Census*, we compile a digital economy input-output table that distinguishes digital trade from traditional trade. Second, digital trade exports as an exogenous final demand shock in the Leontief demand-driven framework, and construct a digital trade export driven model to systematically quantify the value-added effects of digital trade exports at the sector level and decompose them into direct and indirect value-added effects. Finally, we build a digital trade export production network, identify its core sectors, and employ structural analysis methods to identify the paths through which the value-added effects of digital trade exports are transmitted within the production network.

This paper makes three contributions. First, we expand the data foundation for digital trade and input-output accounting. Based on the correspondence between China *Statistical Classification of the Digital Economy and Its Core Industries* (2021) and the *Industrial Classification for National Economic Activities* (GB/T 4754-2017), we design a sectoral classification for a digital economy input-output table that distinguishes digital trade from traditional trade. *China Statistical Yearbooks*, *China Economic Census Yearbook*, *Customs Trade Statistics*, and industry reports are integrated to estimate detailed sectoral proportion coefficients of digital content. Using these coefficients, we compile a 2023 digital economy input-output table that distinguishes digital trade from traditional trade. Second, we broaden the analytical perspective on the value-added effects of digital trade exports by incorporating them as an exogenous final demand shock into the Leontief demand-driven framework. From a value creation perspective, we systematically quantify the direct and indirect value-added effects of digital trade exports across industries, thereby revealing how export demand shocks propagate through intersectoral input-output linkages. Third, we extend the structural analysis of the value-added effects of digital trade exports. We incorporate production network theory into this analysis, construct a digital trade export production network, identify core sectors and key paths, and characterize how value-added effects are transmitted through intersectoral linkages.

The remainder of this paper is organized as follows. Section 2 reviews the literature. Section 3 presents the theoretical analysis. Section 4 describes the models and data sources. Section 5 analyzes the results. Section 6 concludes.

2. Literature review

Research on the economic effects of digital trade primarily examines two dimensions: macroeconomic impacts and micro-level firm behavior. At the macroeconomic level, researchers focus on the impact of digital trade on economic growth, the restructuring of global value chains, and industrial transformation (Bajwa et al., 2025). Research indicates that digital trade's contribution to economic growth is influenced by factors, such as digital infrastructure, institutional environments, and market conditions, and often exhibits complex nonlinear characteristics. Zhao and Yang (2024) found that digital trade exerts a U-shaped influence on the development of a unified large market. Zhu et al. (2022) further noted that digital trade drives consumption upgrading by stimulating innovation and expanding both supply and demand. Additionally, digital trade facilitates the restructuring of global value chains and changes in how industries are organized. By enabling digital goods and services to enter global value chains, digital trade alters how value is created globally and how value-chain revenues are distributed, giving rise to new value chain structures (Xu and Xia, 2020).

At the microeconomic level, researchers primarily investigate the impact of digital trade on firms' export capabilities, participation in global value chains, and ability to create value added. Digital trade exports enhance firms' participation in, and resilience across, global networks, thereby reshaping their export strategies and capacity to generate value added. Geng et al. (2022) found that an increase in a firm's centrality within the digital service trade network can significantly raise its domestic value-added export rate by facilitating domestic specialization in production and stimulating innovation. This effect is particularly pronounced in high-income countries with high levels of digitalization and strong institutions.

Research on the mechanisms through which digital trade promotes economic growth primarily focuses on foreign direct investment, green technological innovation, digital innovation capacity, and reduced information asymmetry. On the one hand, digital trade enhances economic resilience through channels including the development of new economic sectors, foreign direct investment, and green technological innovation (Kong et al., 2024). On the other hand, digital trade reduces market transaction costs and export uncertainty by improving information transmission efficiency and optimizing supply-demand matching mechanisms. From the perspective of supply-demand matching, Yu and Yin (2025) argued that trade digitalization improves supply-demand matching and reduces information asymmetry and matching costs, thereby effectively mitigating the risk of disruption to corporate export relationships and enhancing the sustainability and stability of exports.

Furthermore, the distinct trade characteristics of digital trade operate through different mechanisms. Cheng and Yan (2025) distinguished between digitally ordered and digitally delivered trade. They found that digitally ordered trade is primarily driven by economies of scale and the synergies arising from supply chain digitalization, whereas digitally delivered trade relies on the multiplier effects of data factors and deep integration into global value chains to effectively drive corporate digital innovation. Additionally, digital trade rules strengthen the resilience of digital service export networks by enhancing digital innovation capabilities, optimizing the institutional environment, and mitigating fluctuations in import demand (Jing et al., 2025).

Researchers have analyzed the role of production networks in influencing economic growth and other economic outcomes (Bahari et al., 2024; Deng et al., 2025), primarily following two lines. First, production networks are viewed as transmission structures through which economic shocks propagate and are amplified. This line of research focuses on how input-output linkages facilitate the diffusion of sector-specific shocks across industries. Second, researchers view production networks as dynamic and evolving forms of economic organization and investigate how their endogenous evolution reshapes industrial structures and influences long-term economic growth. Regarding the shock transmission effects of production networks, Long and Plosser (1983) were the first to incorporate input-output linkages into a macroeconomic analysis framework, highlighting that intersectoral input-output relationships serve as a key channel for shock transmission. Subsequently, Acemoglu et al. (2012) further developed a production network model, revealing that the complex input-output connections among sectors allow a specific shock affecting a particular sector to propagate to other sectors along supply chain linkages and to generate an amplification effect through the network structure. As the division of labor deepens, intersectoral linkages become increasingly strong, making the production network structure a crucial factor in determining how micro-level shocks translate into macroeconomic fluctuations.

The aforementioned literature viewed production networks as relatively fixed structures for shock transmission, whereas another branch of literature further emphasizes the endogenous evolution of production networks. They argued that production networks serve not only as channels for transmitting economic shocks, but also as an important source of economic growth. Acemoglu and Azar (2020) pointed out that production networks continuously adjust in response to technological progress, cost fluctuations, and firm-level decisions, generating sustained growth effects through the optimization of input structures. Guo (2025) further treated production networks as endogenous to technological progress. The research developed a macroeconomic framework for structural transformation that incorporates network evolution and reevaluated the impact of technological progress on China's industrial structure transformation during 1995-2022. They found that neutral technological progress in the secondary industry not only directly drives industrial structure transformation, but also drives the evolution of production networks by altering input-output relationships. Neglecting the evolution of production networks would significantly overestimate the economic effects of technological progress. The aforementioned studies demonstrate that production networks not only capture input-output linkages between sectors, but also provide an important analytical tool for identifying the transmission scope and paths of economic shocks across sectors.

The existing literature provides a robust foundation for understanding the economic effects of digital trade and production networks. However, there remains considerable room for further exploration. First, studies on digital trade primarily focus on direct effects, such as growth in the digital trade scale, improvements in firm performance, and technological innovation, while lacking a systematic analysis of the indirect value-added effects generated by digital trade exports through intersectoral input-output linkages. Second, research on production networks has primarily focused on how economic shocks or technological progress affect growth. However, how digital trade is embedded in production networks and how it generates value-added effects through intersectoral input-output linkages have yet to be adequately explored. Third, few studies have combined digital trade exports with digital economy input-output accounting. Moreover, limited attention has been given to the roles of different sectors and the pathways through which value-added effects are transmitted. To address these gaps, we incorporate digital trade exports as an exogenous final demand shock into a production network analysis framework. We construct a digital economy input-output table that

distinguishes digital and traditional trade, measure the value-added effects of digital trade exports from a value creation perspective, and identify key sectors and core paths through network centrality and structural path analysis.

3. Theoretical analysis

3.1. The Value-added effect of digital trade exports

Based on the conceptual framework outlined in the *Handbook for Measuring Digital Trade* (*Second Edition*) (IMF et al., 2023), we define digital trade as trade involving the ordering and/or delivery of goods and services via digital ways. When digital trade exports enter the domestic production system, they first generate an increase in final demand for the relevant exporting sectors, which stimulates corresponding production activities. Accordingly, the value-added effect of digital trade exports refers to the value added generated when digital trade exports are treated as an exogenous final demand shock, given the input-output structure and technological coefficients.

From the perspective of value creation, value added refers to the new value created by production activities, calculated as total output minus intermediate inputs. When final demand generated by digital trade exports enters the domestic production system, it directly increases output in exporting sectors. The production generates value added, including labor compensation, operating surplus, and net production taxes. To meet the additional demand, exporting sectors also require more raw materials, intermediate goods, and producer services. This, in turn, creates additional demand for other sectors. As these sectors expand production, they require more intermediate inputs in turn, further generating production demand and value added. Consequently, the demand generated by digital trade exports propagates through intersectoral input-output linkages, generating value added beyond the initial exporting sectors.

Consequently, the value-added effect of digital trade exports can be divided into direct and indirect effect. The direct value-added effect refers to the value added generated when final demand for digital trade exports directly stimulates production in exporting sectors. The indirect value-added effect refers to the value added generated as demand for intermediate inputs propagates through successive rounds of input-output linkages. These two effects constitute the value-added effect driven by a demand of digital trade exports.

3.2. The Value-added effect of digital trade exports through production networks

Production network theory provides a crucial analytical perspective for understanding how shocks to digital trade export propagate across sectors. Modern production systems form interdependent networks through intermediate input relationships. When demand for the output of a given sector expands, increased production in that sector raises its demand for intermediate inputs. This demand then propagates to related sectors through input-output linkages, giving rise to multiple rounds of cross-sectoral demand transmission. Consequently, production networks not only determine how widely external demand shocks propagate but also influence the scale of value added generated as the initial demand shock spreads across sectors.

Sectors within a production network occupy distinct structural positions and exhibit varying degrees of interdependence. Consequently, their capacity to absorb and transmit shocks to digital trade

export demand also varies. Sectors with extensive input linkages and strong upstream and downstream connections can draw more production stages into the transmission of demand shocks. This enables related sectors to benefit from additional demand across a wider range of activities. In the context of digital trade exports, sectors such as electronic components, communication equipment, computers, and information technology services may not only directly participate in digital trade export production but also establish extensive input linkages with other sectors, including manufacturing and producer services. When digital trade export demand for these sectors rises, the resulting increase in production may spread to other sectors through intermediate input linkages. Thus, the value-added effect of digital trade exports is also closely tied to the structural positions of relevant sectors within the production network and the extent of their input interdependencies.

Furthermore, the network effect of digital trade exports manifests as a continuous transmission process across multiple nodes, layers, and paths. When a digital trade exports shock enters the production network, it gives rise to multiple paths through industrial chains, and these paths intersect and converge across sectors. For example, digital trade export demand may spread to manufacturing along the path electronic components → communication and radar equipment → manufacturing, or generate multi-layered indirect effects along the path information technology services → producer services → manufacturing. The number of sectors traversed by each path, the strength of intersectoral input linkages, and the positions of key nodes vary across paths. Consequently, the resulting value-added effects also differ significantly. Therefore, the value-added effect of digital trade exports reflects how an initial shock to digital trade export demand propagates, accumulates, and is amplified along paths within a complex production network.

4. Model construction and data sources

In this section, we construct an analytical framework encompassing three dimensions, overall effects, network structure, and transmission path, to systematically examine the value-added effects of digital trade exports transmitted through production networks. First, at the overall effects level, a demand-driven model for digital trade exports is developed to measure the value-added effect of digital trade exports. We then decompose these effects into direct and indirect components, thereby providing a comprehensive assessment of the value-added generated by digital trade exports. Second, at the network level, network centrality metrics are employed to assess the connectivity and transmission capacity of different sectors within the digital trade export production network, determine their structural position, and identify the core hub sectors that play a pivotal role in transmission. Finally, regarding the path, the structural path analysis method is applied to trace how demand for digital trade export propagates through intersectoral input-output linkages, measure the value added generated along industrial chains and across multiple paths, and analyze the contribution of each path.

4.1. Construction of an Input-Output model of digital trade export demand

The above analysis demonstrates that the value-added effects of digital trade exports exhibit the characteristics of transmission through a production network. The key question is how initial demand for digital trade exports generates value-added throughout the entire production system through intersectoral input-output linkages. Input-output theory provides an effective analytical tool to depict this mechanism. The input-output analysis method proposed by Leontief in 1936 (Leontief, 1936)

systematically captures complex production interdependencies among sectors of the national economy through an intersectoral input-output matrix (Leontief, 1970). Within this framework, Leontief's demand-driven model posits that changes in final demand not only directly affect the sectors producing final goods but also give rise to multi-level production demand through intersectoral input-output linkages, thereby generating a multiplier effect.

Treating digital trade exports as a final demand shock within the input–output framework allows us to analyze their effects on the production system. Initial demand for digital trade exports first prompts relevant sectors to expand production, generating direct value added. Subsequently, the demand for intermediate inputs arising from this production expansion is transmitted to other sectors through intersectoral input linkages, generating indirect value added across multiple rounds of production. Thus, the value-added effect of digital trade exports can be expressed as the value-added generated as the initial digital trade export demand shock propagates through input-output linkages. The overall effect comprises direct and indirect value-added effects.

In this study, we use a digital economy input-output table that distinguishes digital trade from traditional trade, incorporates digital trade exports as exogenous final demand into the Leontief demand-driven model, construct an input-output model of digital trade export demand, and calculate the value-added effect of digital trade exports.

Let A denote the direct consumption coefficient matrix, then the Leontief inverse matrix is given by

$$L = (I - A)^{-1} \quad (1)$$

Here, I denotes the identity matrix.

Let the digital trade export vector be denoted by DEX; then the total output of digital trade exports X_{DEX}, is given by

$$X_{DEX} = LDEX \quad (2)$$

Let the value-added vector be denoted by V and the value-added coefficient vector by v, which is given by Equation (3).

$$v = V/X \quad (3)$$

Equation (3) represents the value-added generated per unit of output. Thus, the value-added effect of digital trade exports can be expressed as

$$V_{DEX} = v(I - A)^{-1}DEX = vLDEX = mDEX \quad (4)$$

Here, $m = vL = v(I - A)^{-1}$ represents the value-added multiplier. V_{DEX} denotes the total value-added generated by digital trade exports. That is, the value-added induced by each unit of final demand for digital trade exports under given production technologies and intersectoral linkages, and encompasses both direct and indirect value-added effects.

When digital trade exports enter the production system as final demand, they not only directly stimulate production in digital trade exporting sectors but also generate multiple rounds of indirect production demand through intersectoral input-output linkages. To distinguish between the direct and indirect value-added effects of digital trade exports, we decompose the Leontief inverse matrix as follows:

$$L = I + (L - I) = I + AL \quad (5)$$

Accordingly, the value-added effect of digital trade exports can be decomposed into direct and indirect value-added effect.

$$V_{DEX} = V_{direct} + V_{indirect} \quad (6)$$

The direct value-added effect V_{direct} primarily reflects the value added generated by production in sectors that directly meet demand for digital trade exports. The indirect value-added effect $V_{indirect}$ captures the value added generated as demand for intermediate inputs propagates through successive rounds of input-output linkages.

Direct value-added effect V_{direct}:

$$V_{direct} = \upsilon DEX \quad (7)$$

Indirect value-added effect $V_{indirect}$:

$$V_{indirect} = \upsilon ALDEX \quad (8)$$

4.2. Construction of a digital trade export production network

The indirect value-added effect of digital trade exports primarily arises as demand propagates through input-output linkages across sectors, giving rise to a digital trade export production network with directed and weighted links. Therefore, in this section, we further examine how the effects of digital trade exports are transmitted through intersectoral input-output linkages. Within the input-output framework, we construct a digital trade export production network using a production network approach. The structural positions of various sectors in the production network are characterized across three dimensions: connection breadth, connection scale, and network position. We then identify the core hub sectors that play a pivotal role in shock transmission.

The intersectoral product transaction matrix serves as the core dataset for constructing the digital trade export production network. It records the transactions of intermediate goods among various sectors associated with digital trade export, capturing the technological linkages and economic dependencies underlying the production process. The intersectoral product transaction matrix Z_{DEX} is defined in Equation (9).

$$Z_{DEX} = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix} \quad (9)$$

Element z_{ij} represents the scale of intermediate goods purchased by sector j from sector i in its production process to meet the demand for digital trade exports.

We construct a weighted adjacency matrix for the digital trade export production network based on the sectoral output of digital trade exports X_{DEX}.

$$Z_{DEX} = A\hat{X}_{DEX} \quad (10)$$

$\hat{X}_{DEX}$ denotes a diagonal matrix with diagonal elements of the output vector of digital trade exports.

We model the national economy as a directed, weighted production network of digital trade exports, represented by the weighted adjacency matrix. Sectors are the nodes, intersectoral input-output relationships are directed edges, and intersectoral product transactions induced by digital trade exports determine the edge weights.

$$G = (S, E, W) \quad (11)$$

S denotes the set of nodes representing national economic sectors; E denotes the set of directed edges representing the industrial linkages among these sectors; and $W = (w_{ij})$ is the network weight matrix.

In the digital trade export production network, a sector's position depends primarily on the breadth and strength of its production linkages with other sectors. To capture these aspects of network connectivity, we employ out-degree, in-degree, out-strength, and in-strength as measures.

For sector i, its out-degree is defined as:

$$OD_i = \sum_j g_{ij} \quad (12)$$

OD_i indicates how many other sectors a given sector i provides intermediate inputs to, reflecting the downstream supply coverage of that sector. Accordingly, the in-degree is defined as

$$ID_i = \sum_j g_{ji} \quad (13)$$

ID_i indicates the number of other sectors from which sector i receives intermediate inputs, reflecting the scope of its upstream input sources.

The number of connections alone does not adequately reflect the economic magnitude of production linkages. Therefore, we also define sectoral out-strength and in-strength using the magnitude of intermediate input flows induced by digital trade exports.

$$OS_i = \sum_j z_{ij}^{DEX} \quad (14)$$

$$IS_i = \sum_j z_{ji}^{DEX} \quad (15)$$

OS_i denotes the total volume of intermediate inputs that sector i provides to other sectors, reflecting the scale of its supply to downstream sectors; and IS_i denotes the total volume of intermediate inputs that sector i receives from other sectors, reflecting the scale of its demand from upstream sectors.

The number and strength of connections primarily reflect a sector's direct linkages within the network. However, these measures do not capture the network importance of the sectors to which it is connected. To address this, we further employ directed network eigenvector centrality to assess a sector's structural position within the production network.

For the out direction, the outward eigenvector centrality of sector i is defined as:

$$EC_i^{out} = \frac{1}{\lambda_{out}} \sum_j z_{ij}^{DEX} EC_j^{out} \quad (16)$$

λ_{out} denotes the largest eigenvalue of Z_{DEX}. EC_i^{out} not only takes into account the connection between sector i and the downstream sectors to which it supplies inputs, but also further considers the network importance of the downstream sectors to which it is connected. Therefore, a higher outward eigenvector centrality indicates that the sector possesses strong outward hub characteristics.

Correspondingly, the inward eigenvector centrality of a node is defined as

$$EC_i^{in} = \frac{1}{\lambda_{in}} \sum_j z_{ji}^{DEX} EC_j^{in} \quad (17)$$

EC_i^{in} measures the degree of network connectivity between a sector and its key upstream supplier sectors. A higher inward eigenvector centrality indicates that the sector plays a more prominent role as a demand hub.

To make network metrics with different units and scales comparable, we standardize each metric. For any given network metric M_i, its standardized value is calculated as follows:

$$Z(M_i) = \frac{M_i - \overline{M}}{\sigma_M} \quad (18)$$

$\bar{M}$ and σ_M represent the sample mean and standard deviation of the respective indicators, respectively.

Because a single network metric cannot fully capture a sector's connectivity within the production network, we measure its outward and inward connectivity using two dimensions: the breadth and scale of its connections. Specifically, we calculate the sector's outward connectivity by taking the equally weighted average of its standardized out-degree and out-strength.

$$OC_i = \frac{Z(OD_i) + Z(OS_i)}{2} \quad (19)$$

The sectoral inward connectivity is defined as

$$IC_i = \frac{Z(ID_i) + Z(IS_i)}{2} \quad (20)$$

The two outward indicators, out-degree and out-strength, primarily reflect a sector's connections through the provision of intermediate inputs to other sectors. A higher OC_i indicates more extensive input–output linkages with its downstream sectors. The two inward indicators, in-degree and in-strength, reflect a sector's connections through the acquisition of intermediate inputs from other sectors. A higher IC_i indicates more extensive input-output linkages with its upstream sectors.

For each of the four measures - outward connectivity, inward connectivity, outward eigenvector centrality, and inward eigenvector centrality - we calculate the 75th percentile across sectors separately. A sector is classified as high on a measure if its value is greater than or equal to that measure's 75th percentile, and low otherwise. We then apply the following classification rules. A sector with high outward and inward connectivity and high outward and inward eigenvector centralities is classified as a core hub sector. This indicates that the sector maintains input linkages with a broad range of upstream and downstream sectors and has strong connections with sectors of high structural importance within the network. A sector with high outward connectivity but low inward connectivity, and high outward eigenvector centrality is classified as a core outflow sector. This signifies that the sector has strong intermediate input-output linkages and is closely connected to key downstream sectors. A sector with low outward connectivity and high inward connectivity and high inward eigenvector centrality is classified as a core inflow sector. This indicates that the sector has strong intermediate input linkages and is closely connected to key upstream sectors. A sector with low outward and inward connectivity and low outward and inward eigenvector centralities is classified as a marginal sector. All remaining sectors are categorized as general-association sectors.

4.3. Structural path analysis method

The structural path analysis (SPA) method originated with Defourny and Thorbecke (1984), which aims to identify the contribution of each economic sector to the overall effect by representing the Leontief inverse matrix in the form of a power series (Miller and Blair, 2022). The Leontief demand-driven model can measure the value-added effects of digital trade exports. However, it does not directly identify the specific industrial chain paths through which these effects arise. Structural path analysis decomposes the direct and indirect input-output relationships within the Leontief inverse matrix, breaking down the value-added effect of digital trade exports into specific industrial transmission chains, thereby identifying the core paths that contribute most significantly. Therefore, after identifying the hub sectors within the digital trade export production network, we further employ the structural path analysis method to identify the main industrial chain paths through which digital trade export demand generates value added.

The Leontief inverse matrix can be expressed as the following power series, whose terms

represent production paths of different orders:

$$L = (I - A)^{-1} = I + A + A^2 + A^3 + \cdots \quad (21)$$

A corresponds to a path with one intermediate production stage; A^2 corresponds to a path with two intermediate production stages, and so on. We focus on short-chain paths involving the core sectors. Therefore, first- and second-order paths are selected for analysis.

For core outflow sectors and core hub sectors, we examine how the effects of digital trade exports are transmitted from these core sectors to other sectors. Let the core sector be denoted by i, the intermediate sector by k, and the downstream sector by j. The second-order path can then be represented as $i \rightarrow k \rightarrow j$. Based on the input-output relationship, the path coefficient for this path is given by:

$$P_{ikj}^{(2)} = a_{ik}a_{kj} \quad (22)$$

The corresponding path value-added is:

$$V_{ikj}^{(2)} = v_i a_{ik} a_{kj} DEX_j \quad (23)$$

For core inflow sectors and core hub sectors, we further examine how digital trade export demand is transmitted upstream through these sectors. Let the core sector be j, the intermediate sector be k, and the upstream sector by i. The second-order path is denoted as $i \rightarrow k \rightarrow j$, and its path coefficient as well as its path value are calculated using Equations (22) and (23).

To measure the relative importance of different industrial chain paths in the value-added effect of digital trade exports, we define the path contribution as

$$C_p = \left(\frac{V_p}{V_{DEX}}\right) * 100\% \quad (24)$$

V_p denotes the value-added generated along the p-th industrial chain path; V_{DEX} represents the total value added generated by digital trade exports; and C_p enotes the contribution of the p-th path to that total.

4.4. Compile the digital economy input-output table distinguished digital trade and traditional trade

Our analysis requires a 2023 digital economy input-output table that distinguishes digital trade from traditional trade; we therefore compile one for this study.

We select 2023 as the reference year for compiling a digital economy input-output table that distinguishes digital trade from traditional trade for two reasons. First, the input-output table data released by the National Bureau of Statistics has been updated to 2023, providing a recent basis for examining the linkages between China's digital trade and domestic production. Second, the *Fifth National Economic Census* provides annual data for 2023. Compiling the digital economy input-output table requires aggregate data on intermediate output, intermediate input, value-added, final use, and imported intermediate input from the input-output tables, together with detailed data for industry subcategories. The *China Economic Census Yearbook* provides key economic indicators for subcategories across the secondary and tertiary sectors. These census data therefore provide a foundation for the sectoral breakdown needed to compile the 2023 digital economy input-output table

distinguished digital trade from traditional trade and examine the value-added effects and transmission paths of digital trade exports.

4.4.1. Basic table

The digital economy input-output table that distinguishes digital trade from traditional trade is constructed by integrating the digital economy sector and digital trade activities into a unified accounting framework within the traditional input-output accounting system. It enables the simultaneous identification of digital economy sectors and digital trade exports at the sector level, thereby providing a data foundation for analyzing the impacts of digital trade export demand shocks from a value creation perspective. The basic structure of China's digital economy input-output table that distinguishes digital trade from traditional trade is shown in Table 1.

Table 1. Basic Table for the Digital Economy Input-Output Table Distinguished Digital Trade from Traditional Trade in China

Input \ Output			Intermediate Transaction: Digital Sector (1 … 22)	Intermediate Transaction: Traditional Sector (23 … 163)	Consumption	Capital Formation	Export: Digital Trade	Export: Traditional Trade	Import: Digital Trade	Import: Traditional Trade	GrossOutput
Intermediate Transaction	Digital Sector	1 … 22	T^{dd}	T^{dt}	Y_c^d	Y_k^d	Y_{ex-d}^d	Y_{ex-t}^d	IM_{dt}^d	IM_t^d	X^d
	Traditional Sector	23 … 163	T^{td}	T^{tt}	Y_c^t	Y_k^t	Y_{ex-d}^t	Y_{ex-t}^t	IM_{dt}^t	IM_t^t	X^t
Value-added			V^d	V^t							
Gross Input			$X^{d\prime}$	$X^{t\prime}$							

This table follows the structure of the 2023 China Input-Output Table and uses a competitive input-output format. The variables $\boldsymbol{T}$, $\boldsymbol{Y}$, $\boldsymbol{V}$, and $\boldsymbol{X}$ represent the intermediate transaction matrix, final demand matrix, the value-added matrix, and gross output vector, respectively. The superscripts *d* and *t* denote flows associated with the digital and the traditional sectors, respectively. $\boldsymbol{IM}$ is the import vector; $\boldsymbol{IM^d}$ and $\boldsymbol{IM^t}$ represent the total imports of the digital and the traditional sectors, respectively. The subscripts *dt* and *t* denote digital trade imports and traditional trade imports, respectively. $\boldsymbol{T^{dd}}$and $\boldsymbol{T^{tt}}$ represent intermediate transaction within the digital and traditional sectors, respectively. $\boldsymbol{T^{dt}}$ denotes the intermediate inputs from the digital sector used in production by the traditional sector,

while $\boldsymbol{T^{td}}$ denotes intermediate inputs from the traditional sector used in production by the digital sector. The matrices $\boldsymbol{Y^d}$, $\boldsymbol{Y^t}$ represent the distribution of the digital- and the traditional sector products across final demand, respectively. The subscript letters denote the categories of final demand; *c, k, ex* represent consumption, capital formation, and exports, respectively. The matrices $\boldsymbol{V^d}$ and $\boldsymbol{V^t}$ represent value added in the digital and traditional sectors, respectively. Each contains four components: labor compensation, depreciation of fixed assets, net production taxes, and operating surplus. Each column records the value added of the corresponding sector. The vectors $\boldsymbol{X^d}$ and $\boldsymbol{X^t}$ represent gross output in the digital and traditional sectors, respectively.

4.4.2. Compilation method

Compiling a digital economy input-output table that distinguishes digital trade from traditional trade involves a sequence of steps. First, we compile a digital economy input-output table. Then, we integrate sector-specific digital trade data and adjust the table to maintain its accounting balance. Specifically, we follow the methodology proposed by Wang and Li (2026) in three key steps: sector classification, sectoral coordination and transformation, and integration of digital trade data.

First, we identify and classify digital economy sectors. This classification is primarily based on the *Statistical Classification of the Digital Economy and Its Core Industries* (2021) issued by the National Bureau of Statistics of China. We refine it using the correspondence between the *Industrial Classification of the National Economy Activities* (GB/T 4754—2017) and the input-output sector classification. This approach establishes a mapping between core digital economy industries and input-output sectors, which we use to design the sector classification for a digital economy input-output table that distinguishes digital trade from traditional trade.

Second, we carry out sectoral coordination and transformation. During the decomposition and refinement phase, we use the *Industrial Classification of the National Economy Activities* (GB/T 4754—2017) and the correspondence between sector classifications in the standard input-output table and classification of core digital economy industries to identify sectors in the standard input-output table that are wholly or partially classified as digital. We then decompose these sectors as appropriate. Sectors that encompass both digital economy and traditional economic activities are divided into digital and traditional sectors according to the corresponding decomposition ratios. During the consolidation and reorganization phase, the decomposed sectors are regrouped as digital or traditional sectors based on their digital economy attributes. This completes the transition from the standard input-output sectoral classification to the digital economy input-output table sectoral classification. Once the decomposition ratios are obtained, we decompose the intermediate transaction matrix using operating revenue ratio, and the final demand, import, and value-added matrices using the fixed asset investment ratios to derive the digital economy input-output table.

Third, we integrate digital trade information and adjust the table to maintain accounting balance. Using fixed asset investment ratios and sector-specific import and export data from the digital economy input-output table, we construct a coordination transformation matrix to align the sectoral digital trade data for 2023 with the digital economy input-output table. By leveraging the discrepancy between sector-specific total import and export volumes and digital trade volumes, we calculate the traditional trade for each sector, thereby deriving a digital economy input-output table that distinguishes digital from traditional trade.

When integrating digital trade information, we maintain the fundamental input-output accounting identity for each sector: total input equal total output. To preserve the original data structure and avoid

introducing new errors, we adopt the value-added matrix as the target of adjustment. The degree of approximation between substitute indicators and ideal indicators serves as the basis for adjustment. By utilizing intermediate output, intermediate input, value-added, final demand, and imports of each sector, adjustment coefficients are calculated. Adjustments are then applied either to row or column data, as appropriate, to restore the table's accounting balance. This completes the compilation of China's 2023 digital economy input-output table that distinguishes digital trade from traditional trade.

4.4.3. Data sources and processing

In this study, we use operating revenue to decompose the intermediate transaction matrix and fixed-asset investment to decompose the final demand matrix, value-added matrix, and import vector. Operating revenue data are primarily sourced from the *China Economic Census Yearbook* and the *China Industry Statistical Yearbook*; fixed-asset investment data are primarily sourced from the *China Fixed-Asset Investment Yearbook*. For missing operating revenue and fixed-asset investment data, we first use data from comparable years and related indicators for imputation, then supplement the remaining gaps with non-official statistical sources. These sources include the *China Financial Yearbook*, the *China E-Commerce Report*, the *News and Publishing Industry Analysis Report*, the *China Internet Advertising Data Report*, the *China Digital Economy Development White Paper*, and other publications.

The measure digital trade, we use data on imports and exports of digitally ordered goods, the proportion of e-commerce enterprises in each industry that purchase from or sell to regions outside mainland China, industry shares of imports and exports, and service trade statistics. The relevant data are primarily sourced from *China Customs Trade statistics*, supplemented by the *China Economic Census Yearbook 2023*, *China Business Yearbook*, and the *2023 China Input-Output Table*.

5. Results

5.1. The Value-Added effect of digital trade exports

Based on the digital economy input-output table that distinguishes digital trade from traditional trade, we construct a digital trade export driven model to quantify the value-added effects of China's digital trade exports in 2023 and further decompose them into direct and indirect components. To reveal how these impacts of digital trade exports vary across types of sectors, we classify the 163 sectors into 22 digital sectors and 141 traditional sectors according to whether their production activities are classified as digital. This enables us to examine the sectoral distribution and underlying mechanisms of the value-added effects of digital trade exports.

Figure 1 illustrates the value-added effects of digital trade exports across 163 sectors in 2023. The height of each bar represents the total value-added effect of digital trade exports for that sector, while the black and gray areas represent the direct and indirect value-added effects, respectively.

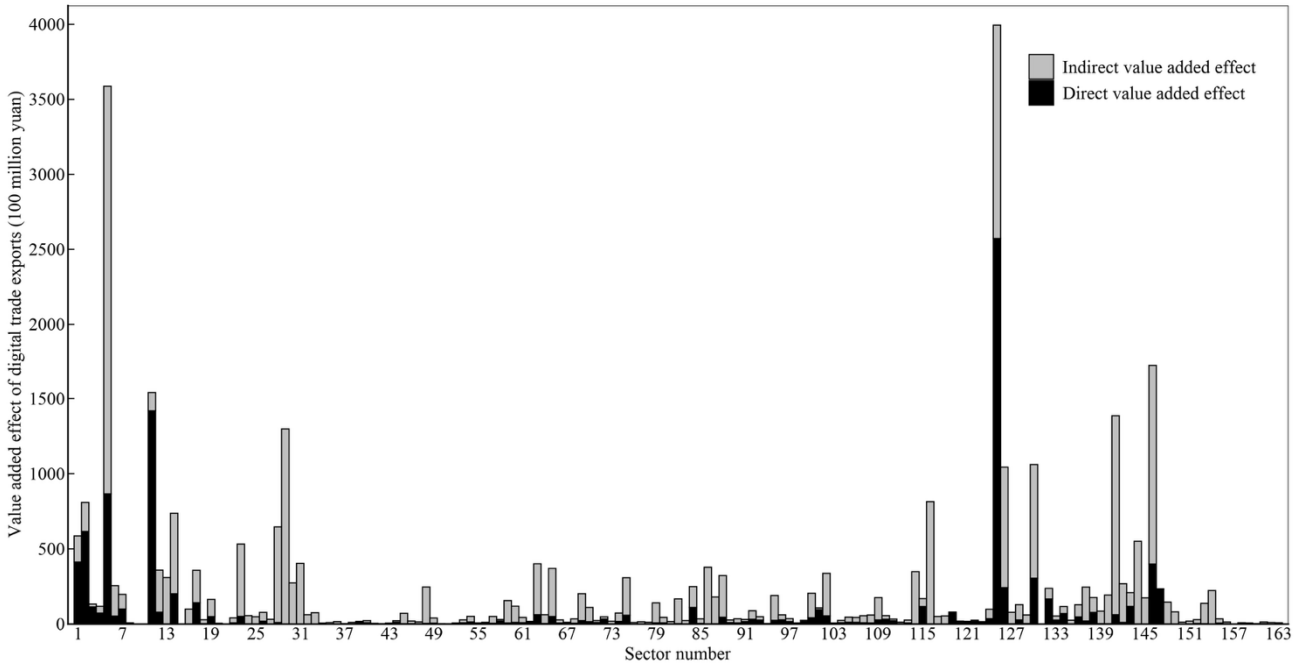


Figure 1. The value-added effect of digital trade exports across 163 sectors in 2023.

In 2023, China's digital trade exports generated a significant value-added effect. Figure 1 shows that in 2023, digital trade exports generated approximately RMB 3.36 trillion in value-added across 163 sectors. It demonstrates that when demand for digital trade exports increases, enterprises expand production and increase their use of labor and capital to fulfill new orders, thereby creating new value added. Moreover, producing goods and services for digital trade exports requires substantial intermediate goods and producer services. This creates new demand for intermediate inputs, prompting related sectors to expand production and generate further value added.

Across sectors, the value-added effect of digital trade exports in 2023 was predominantly concentrated in sectors with strong export demand and substantial production activities. As shown in Figure 1, the value-added effect of digital trade exports was relatively limited in most sectors, whereas a small number of sectors exhibited significantly higher value-added effects. The distribution is therefore highly concentrated. This intersectoral disparity is closely linked to the input requirements and division of labor underlying digital trade exports. Although digital trade exports involve digitally ordered or digitally delivered transactions, producing the goods and services still rely on inputs, such as hardware, software, energy, finance, logistics, and business services. Different sectors have varying input requirements in the production process of digital trade exports. Consequently, their ability to absorb export demand differs significantly. Sectors at key stages of production supply intermediate goods or producer services to multiple sectors. As digital trade exports grow, demand for their output can expand across several production chains, generating larger value-added effects. By contrast, sectors with limited production linkages to digital trade exports receive a smaller increase in demand.

Specifically, the wholesale sector and the electronic components and equipment sector rank highest in terms of the value added generated by digital trade exports. Their value-added of digital trade exports amounted to RMB 399.485 billion and RMB 358.747 billion, respectively, totaling RMB 758.232 billion, accounting for 22.59% of the total value-added generated by digital trade exports. The

wholesale sector performs functions such as commodity procurement, transaction organization, and distribution. As digital trade exports expand, exporting firms require the production of more goods for export and greater use of wholesale services to facilitate transactions. Consequently, growth in digital trade exports also generates demand for wholesale. Electronic components and equipment provide an essential material foundation for the production of digital products, such as computers, communication equipment, and digital media equipment. The expansion of digital trade exports stimulates the production of related digital products, generating additional demand for electronic components and equipment. As a key input sector, electronic components and equipment absorb demand from multiple manufacturing stages.

The next group comprises business services, software development, monetary and other financial services, petroleum and natural gas extraction products, road freight transport and auxiliary transport activities, and retail. These sectors provide inputs and supporting services for digital trade exports. The value-added generated by these sectors of digital trade exports each exceeds RMB 100 billion. Among these, software development and information technology services sectors directly participate in the production of goods and services. The financial services alleviate capital constraints in cross-border transactions and business operations. The road transport and retail facilitate the flow of products throughout the production and transaction. Additionally, energy provides essential inputs for the production of digital equipment, the operation of information infrastructure, and the production activities of enterprises.

The value-added effects of digital trade exports in 2023 were transmitted largely through indirect channels, with the indirect effect exceeding the direct effect. Figure 1 shows that the indirect value-added effect represented by the gray segments, typically accounts for a substantial share of the total value-added effect. Overall, the direct value-added effect was RMB 1016.849 billion, whereas the indirect value-added effect was RMB 2339.464 billion, approximately 2.3 times as large. This indicates that digital trade exports generate value added both directly in exporting sectors and indirectly as export demand raises the need for intermediate inputs throughout the domestic production system. In turn, it stimulates production in other sectors, triggering successive rounds of activity across production stages and generating further value added. Specifically, when the digital trade export sectors receive overseas orders, they purchase more intermediate inputs, including electronic components, energy, transportation, financial services, and business services. In response to this demand, the supplying sectors, in turn, purchase additional inputs from other sectors. Through this process, the initial demand for digital trade exports can give rise to multiple rounds of derived demand within the domestic production system, generating indirect value added that exceeds the value added generated directly in exporting sectors.

There are significant differences between the direct and indirect value-added effects of digital trade exports across sectors, indicating substantial sectoral heterogeneity. On the one hand, Figure 1 shows that the black segments representing direct effects are particularly prominent in the wholesale sector and the software development sector, suggesting that in 2023, the direct value-added generated by digital trade exports was concentrated in these two sectors. The direct value added generated in the wholesale sector was RMB 257.266 billion, ranking first among all sectors. This indicates that digital trade exports first generate substantial direct production demand through trade organization and commodity circulation channels. The direct value-added generated in the software development sector was RMB 141.823 billion, accounting for 92.12% of its total value-added effect. This demonstrates that the value-added creation in the software development sector stems largely from the direct demand

generated by digital trade exports, making it a key sector for the direct value creation driven by digital trade exports.

On the other hand, the indirect value-added generated by digital trade exports in 2023 extended across a wider range of sectors. The electronic components and equipment sector recorded the highest indirect effect, at RMB 272.169 billion, significantly exceeding its direct effect. This indicates that most of the value-added generated in this sector arose from production induced indirectly by digital trade exports. The next largest indirect effects were in wholesale, monetary and other financial services, business services, and oil and natural gas extraction products, at RMB 142.220 billion, RMB 132.305 billion, RMB 132.049 billion, and RMB 129.792 billion, respectively. Together with electronic components and equipment, these sectors span digital hardware, trade circulation, financial services, producer services, and energy inputs. These results demonstrate that how demand for digital trade exports propagates through input-output linkages across production stages, generating substantial indirect value added through successive rounds of demand for intermediate inputs.

5.2. *Identification of digital trade export production networks and hub sectors*

Our findings from the previous analysis indicate that the value-added effects of digital trade exports exhibit significant indirect transmission, extending beyond exporting sectors to other parts of the production system. However, through which intersectoral linkages are these indirect effects transmitted? Which sectors play a pivotal role in this process? To address these questions, we represent production linkages induced by digital trade exports as a directed production network. Using six indicators, out-degree, in-degree, out-strength, in-strength, outward eigenvector centrality, and inward eigenvector centrality, we characterize the structural positions of sectors within this digital trade export production network along two dimensions: network connectivity and sectoral centrality. Table 2 primarily presents the sectors classified as core hubs, core outflow sectors, and core inflow sectors in the 2023 digital trade export production network. The differences among the three categories reflect the direction of their connections within the input-output network: core hub sectors connect both sectors that use their output and sectors that supply their inputs; core outflow sectors primarily connect to sectors that use their output; and core inflow sectors primarily connect to sectors that supply their inputs.

First, core hub sectors possess strong connections in both directions and serve as key nodes within the digital trade export production network. The results presented in Table 2 indicate that the core hub sectors: computers, electronic components and equipment, other digital products, and information technology services, as well as traditional sectors, such as refined petroleum and nuclear fuel processed products, basic chemical raw materials, synthetic materials, steel rolling products, non-ferrous metals and their alloys, wholesale trade, road freight transport, and business services. These sectors exhibit high out-degree and in-degree, indicating that they maintain production linkages with a wide range of other sectors. Consequently, core hub sectors occupy important positions within the production network. Their structural characteristics facilitate the transmission of digital trade export demand shocks across production stages through input-output linkages.

Table 2. Classification results for the three core sectors in the 2023 digital trade export production network.

Sector type	Sector	Sector name	Out-degree	In-degree	Out-strength	In-strength	Outward eigenvector centrality	Inward eigenvector centrality	Outward connectivity	Inward connectivity
Core	1	Computers	161	118	827.48	3522.16	0.02	0.16	0.71	2.02
Hub	5	Electronic components and equipment	160	130	6681.62	7086.54	0.06	0.08	4.95	4.76
Sector	6	Other digital products	161	135	681.48	626.95	0.02	0.01	0.60	0.83
	14	Information technology services	160	114	1234.86	1066.13	0.02	0.05	0.99	0.30
	63	Refined petroleum and nuclear fuel processed products	161	125	1554.52	1445.32	0.02	0.00	1.24	0.96
	65	Basic chemical raw materials	145	124	1232.10	1112.98	0.02	0.00	0.87	0.71
	69	Synthetic material	150	123	765.68	681.81	0.01	0.00	0.57	0.40
	75	Plastic product	160	124	791.98	706.62	0.02	0.00	0.67	0.45
	84	Steel rolling products	148	126	821.06	1339.64	0.01	0.00	0.60	0.94
	86	Non-ferrous metals and alloys	115	130	1933.44	1565.55	0.05	0.01	1.13	1.23
	87	Non-ferrous metal rolling products	127	128	1135.43	971.64	0.03	0.01	0.65	0.78
	88	Metal	161	131	946.13	812.20	0.02	0.00	0.79	0.79
	95	Other general-purpose equipment manufacturing*	159	125	482.19	377.86	0.01	0.00	0.44	0.28
	100	Other special-purpose equipment*	158	127	458.27	389.34	0.01	0.01	0.42	0.37
	102	Motor vehicle parts and accessories	161	121	780.77	689.91	0.02	0.01	0.67	0.33
	109	Battery	161	122	698.31	677.21	0.01	0.01	0.61	0.36
	116	Electricity and heat production and supply	161	124	1787.03	977.25	0.04	0.01	1.40	0.63
	125	Wholesale *	161	113	2230.08	2360.36	0.05	0.04	1.72	1.08
	130	Road freight transport and transport support activities	161	116	1758.85	1488.38	0.03	0.01	1.38	0.64
	146	Business services *	161	110	3066.72	2493.49	0.06	0.05	2.33	1.05
Core	13	Internet-related services	161	107	996.24	687.49	0.02	0.03	0.83	-0.22
Outflow	16	Internet platform	161	100	344.72	245.04	0.01	0.01	0.36	-0.77
Sector	23	Agricultural products	160	121	646.41	193.41	0.01	0.00	0.57	0.01
	126	Retail *	161	115	1177.08	491.72	0.02	0.01	0.96	-0.03
	137	Loading, unloading, handling and warehousing	161	108	393.71	188.17	0.01	0.00	0.39	-0.50
	138	Postal services	161	99	318.57	435.42	0.01	0.00	0.34	-0.69
	140	Catering services	161	118	523.60	336.81	0.01	0.00	0.49	-0.01
	141	Monetary and other financial services*	161	105	1504.93	191.95	0.03	0.00	1.20	-0.61
	142	Capital market services	161	105	448.59	201.65	0.01	0.00	0.43	-0.60
	144	Real estate	161	114	759.77	209.12	0.02	0.00	0.66	-0.25
	145	Rent *	161	100	388.42	214.14	0.01	0.00	0.39	-0.79
	154	Other services *	161	116	419.72	196.84	0.01	0.00	0.41	-0.18
Core	3	Digital media equipments	154	118	117.85	1206.22	0.00	0.06	0.14	0.54
Inflow	4	Smart equipment	160	126	162.18	322.52	0.00	0.01	0.22	0.29
Sector	11	Software development	3	100	111.39	2420.64	0.00	0.10	-1.12	0.62
	101	Automobile	19	123	16.10	397.51	0.00	0.01	-1.05	0.22

Among these, computers and electronic components and equipment stand out for their network connectivity. The out-degree and in-degree of computers are 161 and 118, respectively. The corresponding values for electronic components and equipment are 160 and 130. The results indicate that both sectors have extensive production linkages throughout the production system. Moreover, the out-strength and in-strength of electronic components and equipment are 6681.62 and 7086.54, respectively. Both are relatively high among core hub sectors, demonstrating that this sector combines numerous connections with substantial volumes of intersectoral transactions. Its outward and inward connectivity values are 4.95 and 4.76, respectively, indicating that it is connected to sectors that are themselves importance within the network. The computer sector has outward and inward eigenvector centrality values of 0.02 and 0.16, respectively. Its inward eigenvector centrality indicates connections to important upstream supplier sectors within the network. The out-degree of information technology services is 160, with an out-strength of 1234.86, suggesting extensive outflow connections. The out-strength of the business services sector reaches 3066.72 and an outward eigenvector centrality of 0.06, further demonstrating its network influence. Thus, key nodes within the digital trade export production network also include traditional sectors that supply energy, raw materials, productive services, and distribution services.

Second, core outflow sectors are primarily characterized by strong outward connectivity. They include internet-related services, internet platforms, agricultural products, retail, loading, unloading, and warehousing, postal services, catering and food services, monetary and other financial services, capital market services, real estate, and other sectors. These sectors generally exhibit high out-degree or out-strength, whereas their inward connectivity is relatively weak. For example, the out-strength of monetary and other financial services sector reaches 1504.93, and its outward connectivity is 1.20, whereas its inward connectivity is only −0.61. The outward connectivity of internet platforms is 0.36, while its inward connectivity is −0.77. These results indicate that core outflow sector supply intermediate inputs to large number of other sectors, while their connections to upstream suppliers are relatively limited.

Finally, core inflow sectors are primarily characterized by strong inward connectivity. They include digital media equipment, smart equipment, software development, and complete automotive manufacturing. These sectors exhibit relatively high in-degree and in-strength, whereas their outward connectivity capability is relatively weak. For example, the in-degree of the software development sector reaches 100, its in-strength reaches 2420.64, and its inward connectivity is 0.62. The in-strength of the digital media equipment sector reaches 1206.22, and its inward connectivity is 0.54. This indicates that the sectors are connected to numerous upstream suppliers and obtain substantial intermediate inputs from them. Software development sector exhibits relatively typical core inflow sector. Its in-strength of 2420.64 is high among core inflow sectors, suggesting that software development activities require substantial intermediate inputs. Digital media equipment and smart equipment hold a prominent position in the input network, indicating that their production activities are closely linked to multiple upstream sectors through input-output relationships.

5.3. *The Paths of the digital trade export production network*

To explore how key sectors transmit shocks to digital trade export demand, we use the three categories of core sectors identified above as starting points for structural path analysis and trace how the value-added effects of digital trade exports propagate through intersectoral input-output linkages.

Table 3 presents the main paths within the 2023 digital trade export production network, along with their corresponding value-added effects and contribution rates.

Table 3. Primary paths of the 2023 digital trade export production network, along with the corresponding path value-added and contribution rates.

No.	Key paths for hub sectors	Path value-added (RMB 100 million)	Path contribution rate
1	Electronic components and equipment → Communication and radar equipment	402.06	1.20
2	Electronic components and equipment → Computers	360.82	1.08
3	Information technology services → Software development	165.06	0.49
4	Petroleum and natural gas extraction products → Refined petroleum and nuclear fuel processed products	154.30	0.46
5	Business services → Software development	138.63	0.41
6	Business services → Wholesale	138.11	0.41
7	Electronic components and equipment → Digital media equipment	137.98	0.41
8	Monetary and other financial services → Wholesale	129.79	0.39
9	Wholesale → Communication and radar equipment	127.35	0.38
10	Telecommunications, radio and television, and satellite transmission services → Software development	115.64	0.34

Table 3 shows that value-added effects in the digital trade export production network are concentrated along a small number of paths. Among the top 10 paths, electronic components and equipment → communication and radar equipment generated the largest contribution at RMB 40.206 billion, accounting for 1.20% of the total value-added effect. Electronic components and equipment → computers generated RMB 36.082 billion in value-added, accounting for 1.08%. Both paths contributed more than 1%, exceeding the shares of the other paths. Furthermore, each of the top 10 paths generated more than RMB 10 billion in value added. Together, these results indicate that a small number of industrial chains play a particularly important role in transmitting the indirect value-added effects of digital trade exports.

In terms of sectoral composition, production linkages within the digital economy and between digital and traditional sectors form important structural pathways for transmitting the value-added effects of digital trade exports. Specifically, the value-added amounts for the three paths: electronic components and equipment → communication and radar equipment, electronic components and equipment → computers, and electronic components and equipment → digital media equipment, generate value added of RMB 40.206 billion, RMB 36.082 billion, and RMB 13.798 billion, respectively, and account for 1.20%, 1.08%, and 0.41% of the total effect. All three paths originate in electronic components and equipment and extend to other digital sectors, such as communications and radar equipment, computers, and digital media equipment. This indicates that electronic components and equipment, as critical intermediate inputs in the production of digital products, form relatively dense production linkages with digital hardware sectors, such as communication and radar equipment, computers, and digital media equipment. Changes in demand for electronic components and equipment are transmitted through these digital-sector production linkages, generating substantial value-added effects.

Moreover, the value-added effects of digital trade exports also extend to traditional production sectors. The path petroleum and natural gas extraction products → refined petroleum and nuclear fuel processed products generates RMB 15.43 billion in value-added, while the paths business services→ wholesale and monetary and other financial services → wholesale generate RMB 13.811 billion and RMB 12.979 billion, respectively. These paths demonstrate how shocks to digital trade export demand propagate through input-output linkages, generating demand for intermediate inputs from traditional sectors, including energy, business services, financial services, and distribution, and creating value-added in those sectors.

From the perspective of inward linkages, software development is the endpoint of several important paths. Specifically, the paths information technology services → software development, business services → software development, and telecommunications, radio and satellite transmission services → software development generated value added of RMB 16.506 billion, RMB 13.863 billion, and RMB 11.564 billion, respectively, accounting for 0.49%, 0.41%, and 0.34% of the total value-added effect. This indicates relatively strong input-output linkages between the software development and information technology services, business services, and telecommunications, radio and satellite transmission services. Moreover, when a shock to digital trade export demand generates derived demand for software development, production in this sector creates further demand for intermediate inputs. The demands shock can then propagate to its input-supplying sectors, generating additional value-added.

Comparing different types of core paths reveal two representative transmission mechanisms within the digital trade export production network. The first involves input linkages between the digital manufacturing sectors, represented by electronic components and equipment, and digital product production sectors, such as communication equipment, computers, and digital media equipment. These paths reflect strong intermediate input linkages between digital manufacturing and digital product production. The second mechanism involves input linkages between producer service sectors, including information technology services, business services, and telecommunications services, and digital service sectors, such as software development. These paths show how producer services contribute inputs to digital service production. Additionally, traditional sectors, including energy, finance, and trade and distribution, participate in production related to digital trade exports through input-output linkages, thereby extending the value-added effects of digital trade export to these sectors.

Individual paths account for relatively small shares of the total value-added effect. Among the top 10 paths, even the largest contribution, from electronic components and equipment → communication and radar equipment, is only 1.20%. This indicates that the indirect value-added effect of digital trade exports arises from the combined influence of multiple rounds of intersectoral input-output linkages. Furthermore, a small number of paths generate more value-added and make larger contributions than other individual paths, giving them particular structural importance. Consequently, the indirect value-added effect of digital trade exports reflects both the prominence of a few key paths and the spread of demand across many paths.

6. Conclusions

In this paper, we integrate digital trade exports into an input-output analysis framework to systematically examine their value-added effects through production networks across three dimensions: overall effects, network structure, and transmission paths. We then further identify the roles of different sectors and paths in this process. Based on this analysis, we draw the following conclusions.

First, China's digital trade exports generated substantial value added in 2023. The indirect value-added effect exceeded the direct value-added effect. Moreover, digital trade exports not only generated value added directly in exporting sectors but also stimulated production in related sectors through successive rounds of demand for intermediate input. Second, core hub sectors exhibit strong inward and outward connectivity and serve as critical nodes in digital trade export production network. Third, the core paths transmitting the value-added effects of digital trade exports involved two types of linkages: vertical input linkages within digital manufacturing and cross-sector input linkages involving producer services. The paths electronic components and equipment → communication and radar equipment, electronic components and equipment → computers represent important channels through which digital trade exports generated value added.

Although this study examines the value-added effect of digital trade exports from a production network perspective, there is room for further in-depth exploration. First, future research could examine how these value-added effects change over time. We analyze the transmission of digital trade export demand through production networks using the 2023 input-output table. However, the input-output structure changes in response to technological progress, industrial upgrading, and shifts in trade structure. Future research could therefore construct a multi-year digital trade input-output database, employ dynamic input-output models, further investigate the evolution of the digital trade export production network, and identify how value-added effects vary across stages of development.

Second, future research could extend the analysis of the value-added effects of digital trade exports across regions and countries. We primarily examine how digital trade exports demand propagates through domestic industrial linkages. However, digital trade inherently connects economic activities across regions and national borders. Future research could integrate domestic production networks with global value chain networks to investigate how demand for digital trade exports propagates to sectors and regions through cross-regional and cross-border input-output linkages. This would help identify where value added is generated along these paths and how it is distributed across regions.

Third, further research could examine how the structure of production networks shapes differences in the value-added effects of digital trade exports. While we have identified distinct types of sectors, such as core hub, core outflow, and core inflow sectors, these sectors also differ in technological intensity, degree of digitalization, and participation in global market. Future studies could analyze differences by sectoral technology, degree of digitalization, trade mode, and position in the industrial chain. This would allow researchers to compare how sectors in different network positions transmit shocks to digital trade export demand and how much value added they generate. Such analysis would further clarify how network structure shapes the distribution and reach of these value-added effects.

Author contributions

Conceptualization, Zimei Huang, Yafei Wang and Mingna Li; methodology, Zimei Huang; software, Zimei Huang; validation, Mingna Li; formal analysis, Zimei Huang; investigation, Mingna Li; resources, Yafei Wang; data curation, Mingna Li; writing—original draft preparation, Zimei Huang; writing—review and editing, Zimei Huang, Yafei Wang and Mingna Li; visualization, Zimei Huang; supervision, Yafei Wang; project administration, Yafei Wang and Zimei Huang; funding acquisition, Yafei Wang and Zimei Huang.

Use of AI tools declaration

We have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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