Impact of Intellectual Property Protection on the Digital Services Trade Network

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Abstract. This paper constructs a global digital services trade network through social network analysis method based on digital services trade data from 2005 to 2021 and examines the characteristics of network development. It explores the impact of intellectual property protection on countries' standing in the digital services trade network. It is found that the level of intellectual property protection of a country can significantly promotes its network centrality and linkage strength in the digital services trade network, and through heterogeneity analysis, it is found that the level of intellectual property protection of developed countries has a stronger effect on the promotion of the digital services trade network than that of developing countries.

Keywords: level of intellectual property protection; trade in digital services; social network analysis

1 Introduction and Literature Review

With the rapid development of the global digital economy, digital trade in services has expanded traditional trade boundaries and become a key driver of economic growth. In 2020, digital services accounted for 62.8% of global services trade, up from 48.1% in 2011. Unlike traditional trade, digital trade's structure differs significantly. According to the 2020 Handbook on Measuring Digital Trade (OECD, WTO, and IMF), only 7 out of 20 digital trade types are merchandise; the rest are services. The boundaries of digital services trade are blurred due to the bundling of services and goods, marking an evolution from traditional trade.

However, trade in digital services is more susceptible to low-cost copying and dissemination of data than traditional trade, and faces more extensive and insidious risks of infringement, as well as a range of nascent issues such as the free flow of data across borders, security and privacy, source code protection, and digital localization [1].

In past studies on intellectual property rights (IPR) and trade development, some scholars believe that IPR protection can promote trade development and improve trade flows in exporting countries found a non-linear, inverted "U" relationship between IPR protection and export trade [2]. Branstetter et al. found that stronger IPR protection can reduce imitation and increase FDI, boosting goods trade [3]. Chen argued that IPR

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protection fosters independent R&D, increases the supply of IPR-intensive products, lowers their relative prices, and promotes exports [4]. Specifically, for IPR and digital services trade, Sun Yuhong found that IPR protection enhances trade advantage through innovation, investment, and cost reduction [5]. Bing et al.noted that IPR protection safeguards the technological foundation of digital services trade, reducing trade costs and improving global connectivity [6]. Jiang Nan highlighted that IPR protection can safeguard data, crucial for digital services trade [7].

IPR protection also enhances the value and flow of high value-added digital services, such as source codes and software, thereby expanding trade diversity [8]. It helps create a favorable business environment and promotes digital service trade by facilitating key elements and reducing geographical limitations. Ou Zhonghui et al. [9] emphasized that both importing and exporting countries benefit significantly from strong IPR protection in digital service trade.

With economic globalization, trade relations among countries form a complex network of mutual influence. Social network analysis (SNA) examines the regular characteristics of socially relevant nodes connected by relationships within a network, offering a multilateral perspective on inter-country trade relations [10]. This paper focuses on the impact of intellectual property protection on digital service trade, using SNA to construct a digital service trade network. By analyzing the individual characteristics of each country within this network, the study explores how varying levels of intellectual property protection affect digital service trade.

2 Theoretical Analysis

2.1 The Level of IPR Protection Enhances a Country's Network Centrality And Strength of NETWORK LINKAGES in digital Services Trade Networks

IPR protection drives economic growth by fostering innovation, leading to increased GDP and strengthening a nation's role in global trade, particularly in digital services. Strong IP protection builds trust with partners, enhances collaboration, and deepens trade connections. Additionally, it maintains product quality, attracts international partners, and secures data flows, consolidating the country's position in digital trade networks. Furthermore, effective IPR protection attracts investment in digital infrastructure, fueling urban development and the growth of high-tech industries. Ultimately, robust IP protection boosts a country's centrality and connectivity in the global digital services trade network.

H1: Intellectual property protection can significantly increase a country's centrality and linkage strength in digital services trade networks.

2.2 The Level of IP Protection in Developed Countries Enhances the Centrality of Their Networks and the Strength of Their Linkages more than in Developing Countries

Compared to developing nations, developed countries offer stronger intellectual property rights (IPR) protection, creating a reliable business environment for cross-border digital services trade. This protection boosts enterprise credibility and innovation, leading to a competitive edge in the digital sector. Developed nations also provide better resources for expanding operations and fostering international cooperation. In summary, strong IPR protection enhances developed countries' influence in the digital services trade network.

H2: The promotional effect of the level of IP protection in developed countries on their centrality and linkage strength in digital services trade networks is better than in developing countries.

3 Evolution of the Characteristics of Digital Trade in Services Networks

3.1 Construction of a Digital Trade in Services Network

The social network approach comprehensively reflects the complex trade relations among countries around the world by portraying the topology of the network. According to the social network research method, it can be clearly known that the flow of trade goods from the exporting country (the starting node) to the importing country (the destination node), and whether the trade occurs or not as the edge, and the size of the trade flow as the weight. In this paper, the point degree of centrality (degree) is used to measure the network centrality of the node, and the strength (strength) indicator to measure the network connection strength.

Network Centrality

Indicators of network centrality measure the importance of an individual in a trade network in the overall trade network, i.e., the extent to which the individual is the "center" of the network. In this paper, the nodes are the 48 countries (regions) appearing in the network, a country in the trade network is both the exporter and importer of digital services trade, the point into the degree represents the number of countries exporting trade to the country, the greater the degree of entry, indicating that the digital services trade exported to the country the more the country, the higher the degree of participation in the digital services trade network; point out of the degree of the opposite, the sum of the two constitutes the point of the degree of centrality, the greater the node's point of centrality, the greater the node's point of centrality, the greater the node's point of centrality. Center degree, the larger the center degree of the node's point degree, the more the node connects to other nodes in the trade network, the larger the coverage in the trade network.

$$K_i = K_i^{in} + K_i^{out} = \frac{\sum_{j=1}^{N} a_{ji}}{N-1} + \frac{\sum_{j=1}^{N} a_{ij}}{N-1} \quad (1)$$

Strength of Network Ties

Network connection strength is used to represent the size of the connections between nodes in a network. Not only can it reflect the number of times a node contacts other nodes in the network, but also the weight of the links between nodes. The size of the in intensity reflects how much trade flows into the country, the greater the in intensity, the greater the amount of digital services trade exported to the country from other countries; the size of the out intensity reflects how much value-added exports from a country, i.e., the greater the out intensity, the greater the amount of digital services trade sent out from the country. The point intensity, which is the sum of the outward and inward intensities, can be used to measure a country's total trade volume in a trade network, indirectly reflecting the strength of the country's linkages in the trade network.

$$S_i^{degree} = \sum_j^n w_{ij} + \sum_i^n w_{ij} \quad (2)$$

3.2 Evolution of the Overall Network Characteristics of Trade in Digital Services

This paper employs the methodology of Zhou Nianli et al. [11] and Chen Song [12] and utilizes statistical data from the World Trade Organization (WTO), the International Monetary Fund (IMF), and the Organization for Economic Co-operation and Development (OECD) to analyze trade in digital services. It aggregates export values of six sectors classified under the EBOP framework to obtain total digital services exports, constructing a forward-weighted network for digital services trade. The network construction follows the relative weighting method proposed by Deng Huihui , where a threshold value of 0.1% of the export value of digital services trade between two countries is set to determine trade links [13]. This approach effectively filters out edges with smaller weights, retaining the primary structure of the digital services trade network. The resulting dataset covers digital services trade among 48 countries [1] from 2005 to 2021.

Subsequently, Gephi software is utilized for visualizing and analyzing the trade network structure to elucidate its main characteristics. Table 1 presents the overall global digital services trade network characteristics and related data for the years 2005, 2010, 2015, and 2020. Analysis reveals that from 2005 to 2020, the network's density steadily

[1] Including United Arab Emirates, Argentina Australia, Austria, Belgium, Bermuda, Brazil, Barbados, Canada, Switzerland, Chile, China, Costa Rica, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hong Kong, Hungary, Indonesia, India, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Mexico, Philippines, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Spain, Sweden, Switzerland, Switzerland, Switzerland and the United Kingdom. Japan, Korea, Luxembourg, Mexico, Malta, Malaysia, Netherlands, Norway, Philippines, Poland, Russia, Saudi Arabia, Singapore, Sweden, Thailand. Turkey, United States, Venezuela, Vietnam, South Africa

increases, indicating closer connectivity and more frequent trade activities. The average clustering coefficient decreases, suggesting a trend towards network homogenization and increased participation of countries in digital service trade. Moreover, the average path length gradually shortens, implying enhanced efficiency in information transmission and reduced cooperation costs. Meanwhile, the average degree and average weighted degree show continuous growth, indicating increased node connections and strength, leading to a denser network overall.

Figure 1 illustrates the characteristics of the digital services trade network sorted by network centrality from 2005 to 2020. Notably, countries like the United States, the United Kingdom, Germany, and France consistently maintain pivotal roles in the trade network. China's position in the network progressively strengthens, rising from 14th in 2005 to 7th in 2020, thereby assuming a central role in Asia, replacing Japan during 2005-2010. Additionally, countries such as Ireland and Switzerland also gain prominence in the trade network over time.

Table 1. Overall network eigenvalues of trade in digital services, 2005, 2010, 2015, 2020

	2005	2010	2015	2020
average degree	3.792	3.854	4.1.04	4.271
average strength	16076.658	24260.434	32770.283	43992.206
map density	0.081	0.082	0.087	0.091
Average clustering coefficient	0.449	0.372	0.41	0.425
Average path length	1.991	1.973	1.955	1.908

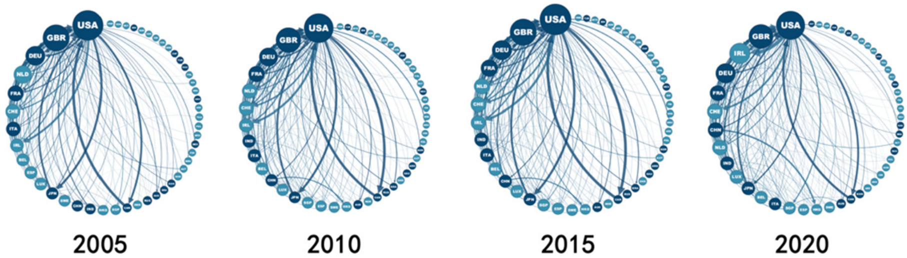

Fig. 1. Overall network characteristics of trade in digital services, 2005, 2020

4 Research Design

4.1 Modeling

In order to explore the impact of the level of intellectual property protection on a country's digital services trade network on an empirical level, the following model is set up:

$$DST_{it} = \alpha + \beta IPR_{it} + \gamma X_{it} + \mu_i + \sigma_t + \varepsilon_{it} \tag{3}$$

where the subscript$i$, the$t$ denote country and year, respectively, and the explanatory variables are the individual characteristics of the digital services trade network, which are characterized by degree ($degree_{it}$) and intensity ($strength_{it}$) are denoted. The core explanatory variableIPR_{it} denotes$i$ country$t$ level of intellectual property protection in the year;X_{it} is the control variable;μ_i are individual fixed effects, theσ_t are year fixed effects, andε_{it} is the error term. The empirical analysis of this paper covers the period 2005-2021, and the range of countries is 46 countries in the node countries of the trade network constructed in the previous section.

4.2 Description of Data

Explained Variables

We employ point degree centrality (degree) and strength metric to depict the centrality of nodes and the strength of network connections, respectively. The methodology for constructing these metrics is detailed in the preceding section. In the robustness test, Eigen-vector Centrality is introduced as an alternative to point degree centrality. This metric accounts for both the node's direct connections and the centrality of its neighboring nodes. A node's importance is determined not only by its own connections but also by the importance of its connected neighbors. If a node is linked to numerous nodes with high centrality, its eigenvector centrality will be higher as well.

Core Explanatory Variables

This paper focuses on the impact of the level of intellectual property protection on the digital service trade network and selects the Legal System & Property Right Index released by the Fraser Institute of Canada as the measure of the enforcement dimension, with a value range of 0-10. In order to ensure the accuracy of the empirical results, the core explanatory variables are replaced by the level of property protection released by the Property Rights Alliance as a substitute in the robustness test. Alliance (Property Rights Alliance) as a proxy for the level of property rights protection.

Control Variables

The control variables in this paper include:

(1) Macroeconomic level (gdp): measured using 2015 constant price GDP data for country i in year t. GDP is used as the main indicator of a country's economic strength.

(2) Level of FDI attraction (ifdi): Measured using data on net FDI inflows in country i in year t. Higher FDI inflows are usually accompanied by inflows of technology and knowledge.

(3) Level of services development (serv): measured using the percentage of people employed in services in country i in year t. Countries or regions with a high level of services development usually have higher competitiveness and activity in digital services trade.

(4) Level of urbanization (urba): Measured using the share of the urban population in the total population of country i in year t. The level of urbanization is closely related

to the development of services, with higher levels of urbanization usually implying more developed services and higher trade activity.

Data Description and Processing

The explanatory variables' data are sourced from the World Trade Organization (WTO), the International Monetary Fund (IMF), and the Organization for Economic Co-operation and Development (OECD), following the methodology outlined in the previous section. These variables are derived from the Legal System & Property Right Index provided by the Fraser Institute of Canada, which gauges law enforcement dimensions on a scale ranging from 0 to 10. Control variables' data are sourced from the World Bank database, and logarithmic transformations are applied to them in the empirical analysis. Table 2 presents the descriptive statistics of the variables.

Table 2. Descriptive statistics of variables

Variable	Obs	Mean	Std. dev.	Min	Max.
degree	782	8.26	11.26	0	55
strength	782	64827.82	126783.20	0	1053166
eigencentrality	782	0.25	0.27	0	1
IPR1	782	7.08	1.95	4.38	9.34
IPR2	645	6.65	1.34	3.20	8.71
gdp	782	1.40e+12	2.96e+12	4.20e+095	2.05e+13
ifdi	782	3.88e+10	7.65e+10	-3.30e+11	7.34e+11
serv	782	67.51	13.40	26.41	89.47
urba	782	74.82	17.29	27.28	100

5 Empirical tests and Analysis of Results

5.1 Benchmark Regression

Table 3 presents the outcomes of a benchmark regression examining the influence of countries' intellectual property rights (IPR) protection levels on their participation in the digital services trade network. Columns (1) and (2) feature explanatory variables including point degree centrality and intensity derived from digital services trade. Following the inclusion of fixed effects, the regression coefficients for IPR protection on these core explanatory variables are all significantly positive at the 1% significance level. This suggests that a country's IPR protection level enhances both its centrality within the network and the strength of its network connections in digital services trade, aligning with theoretical expectations.

Furthermore, the regression coefficients for GDP, FDI inflow, and service employment are all significantly positive at the 1% level, indicating that a country's economic prowess, capacity to attract foreign investment, and level of service sector development positively influence its standing in the digital services trade network. Conversely, urbanization level exhibits a significantly negative impact at the 1% significance level. This suggests that excessive urbanization may adversely affect the centrality and strength of linkages in digital services trade networks. This outcome could be attributed to various factors, such as high living costs in urban areas prompting talent migration to lower-cost regions, thus impacting industry innovation and competitiveness. Additionally, resource over-concentration in urban settings may strain infrastructure, diminishing digital service quality and trade efficiency.

Table 3. Benchmark regression results

	(1)	(2)
	degree	**strength**
ipr1	2.34^{***}	25181.43^{***}
	(8.15)	(6.88)
gdp	3.99^{***}	42270.07^{***}
	(17.58)	(14.64)
ifdi	2.26^{***}	19918.09^{***}
	(9.70)	(6.71)
serv	20.80^{***}	186818^{***}
	(9.27)	(6.56)
urba	-18.88^{***}	-171000.6^{***}
	(-11.72)	(-8.36)
cons	-175.75^{***}	-1771433^{***}
	(-21.52)	(-17.08)
country	control	control
year	control	control
N	729	729
R-sq	0.6607	0.5686

Note: Values in parentheses are standard errors of robustness of the coefficients; *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively, as in the table below.

5.2 Robustness Tests

In order to ensure the robustness of the regression results, this paper chooses to use the replacement of core explanatory variables, replacement of explanatory variables, and changing the sample range to test the robustness of the model. Firstly, the level of property rights protection published by the Property Rights Alliance is used to replace the original core explanatory variables to regress the centrality and linkage strength of the digital service trade network respectively. Since the data range published by the Property Rights Alliance is 2007-2019, the time horizon is reduced in the regression process. The results, shown in columns (1) and (2) of Table 4, indicate that the direction and significance of the regression coefficients of the new core explanatory variables are consistent with the results of the benchmark regression. In order to test whether the estimation results of other network centrality indicators in this regression model are biased, this paper chooses Eigenvector centrality (Eigenvector) to replace the explanatory variables for estimation, and the regression coefficients are significantly positive, and the regression results of the rest of the control variables are also in line with the benchmark regression results.

Table 4. Robustness test regression results

	(1) degree	(2) strength	(3) eigencentrality
ipr1			0.04*** (7.22)
ipr2	2.67*** (8.08)	26664.32*** (6.16)	
gdp	4.12*** (15.20)	45549.79*** (12.83)	0.10*** (20.37)
ifdi	2.10*** (7.60)	19131.71*** (5.27)	0.05*** (10.35)
serv	19.83*** (5.69)	256985.6*** (5.64)	0.65*** (13.33)
urba	-17.80*** (-6.37)	-223212.1*** (-6.10)	-0.43*** (-12.43)
cons	-177.3*** (-17.98)	-1908514*** (-14.80)	-4.89*** (-27.48)
country	control	control	control
year	control	control	control
N	595	595	729
R-sq	0.6642	0.5848	0.7273

5.3 Heterogeneity Analysis

In order to further explore the impact of the level of IPR protection on the network standing of countries with different levels of development on their trade in digital services, this paper conducts a regression by grouping the sample countries according to whether they are developed countries or not. The regression results are shown in Table 5. From the results, it can be seen that the level of IPR protection in developed countries has a more obvious effect on the centrality of their trade networks and the strength of their links than that in developing countries, but the gap between the two is not large. In addition, the significance of IPR protection in developed countries on the strength of their digital services trade networks has decreased, but it does not affect the conclusions of this paper.

Table 5. Heterogeneity analysis regression results

	developed country		developing country	
	(1)	(2)	(3)	(4)
	degree	strength	degree	strength
ipr1	2.27***	22816.02**	2.11***	22289.12***
	(3.99)	(2.94)	(6.29)	(5.62)
gdp	4.75***	49592.35***	3.48***	37084.33***
	(11.40)	(8.74)	(12.61)	(11.35)
ifdi	2.15***	20358.13***	2.31***	18054.08***
	(5.40)	(3.75)	(7.70)	(5.09)
serv	26.61***	258178.5***	18.38***	161426.6***
	(5.46)	(3.90)	(7.27)	(5.41)
urba	-20.61***	-196115.5***	-17.25***	-152924.6***
	(-6.15)	(-4.30)	(-9.35)	(-7.02)
cons	-206.02***	-2148367***	-158.56***	-1542893***
	(-11.94)	(-9.01)	(-17.06)	(-14.06)
country	control	control	control	control
year	control	control	control	control
N	250	250	479	479
R-sq	0.7164	0.6345	0.6352	0.5456

6 Conclusions

This study constructs a global digital services trade network using comprehensive export data, revealing a progressive increase in network density, average degree, and weighted average degree. Conversely, the average clustering coefficient and average path length decline gradually, indicating heightened connectivity, frequency of activity, and network efficiency. Regression analysis spanning 2005-2021 across 46 countries demonstrates a significant positive impact of intellectual property protection on the centrality and connection strength of the digital service trade network. This suggests that reinforcing intellectual property protection can elevate a country's standing in the global digital service trade network. Control variables including GDP, FDI inflows, and the level of service industry development significantly contribute to the network's status. Conversely, urbanization level exhibits a significant negative impact on network centrality and linkage strength, potentially attributed to high living costs and resource imbalances stemming from excessive urbanization.

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