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Research article

How does digital payment affect international trade? Research based on the social network analysis method

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Abstract: Digital payment is one of the latest trendsin modern payment systems; its development has a profound impact on international trade relations and the international trade status of countries. We constructed an international trade network by using global commodity trade data to measure countries' international trade status. Based on this, we used panel data from 25 countries for the period between 2012 and 2020 and employed a fixed-effect model to test the relationship between digital payment and international trade status. Empirical results show that,first, the development of digital payment can effectively enhance a country's international trade status. Second, digital payment strengthens international trade connections by lowering barriers to cross-border capital flows, thereby improving a country's international trade status. Third, the effect of digital payment on enhancing international trade status varies across countries with different degrees of trade openness. The findings of this study provide theoretical support for the development of digital payment and international trade.

Keywords: international trade status; digital payment; social network analysis method; international trade network

1. Introduction

1.1. Research background

International trade refers to the trade of goods and services across borders, which critically affect global technology diffusion, sustainable development, and the economic growth of countries [1–4]. All of these issues are currently the main focus, illustrating the importance of studying international trade [5–8]. International trade has developed into a vast network of global trade, where countries play different roles. Countries situated at the center of the network often reap higher trade dividends and other benefits. Therefore, enhancing a country's international trade status has become an essential aspect of development. Notably, the development of digital payment in recent years has provided new possibilities to tackle this issue.

In the traditional international payment settlement system, SWIFT has long dominated due to its safety and stability. The US dollar occupies a significant position in SWIFT. Therefore, the USA has long held a favorable position in international trade. With the widespread adoption of digital payment, countries have begun developing digital currencies that threaten the dominant position of the US dollar and contribute to promoting better international trade development [9]. For example, China has made significant progress in the promotion of digital payment and e-CNY in recent years, actively promoting the development of a digital payment settlement system in the Asian region and building a "Belt and Road" economic belt centered around the e-CNY. Meanwhile, in 2018, the European Union launched the real-time digital payment settlement system TIPS, which is highly efficient, cost-effective, and significantly improves the overall efficiency of internal trade within the EU. Furthermore, the payment settlement system can also be applied to countries outside of the EU, providing safer and more efficient payment methods for enterprises and customers through the use of TIPS, which could help to enhance the EU's position and competitiveness in international trade.

In summary, digital payment is impacting the existing international trade settlement system, and this will inevitably affect the global trade landscape. Countries with a high level of digital payment development are more likely to occupy important positions in the new international trade landscape. Therefore, the development of digital payment technology may impact countries' international trade status.

Considering this, we have constructed an international trade network by using commodity trade data from 189 countries and measured international trade status based on network characteristics. From this, we selected 25 countries as samples to test the relationship between digital payment and international trade status and explored its mechanisms, pathways, and heterogeneity, considering the data's availability and continuity.

This study's marginal contributions are as follows. First, we contribute to the literature on digital payment effects and the impact of international trade network factors. While many scholars have studied the effects of digital payment, they have mainly focused on the micro-level and have not considered digital payment's application in international trade. Similarly, scholars studying the factors affecting international trade networks tend to focus on traditional factors such as politics, tariffs, and exchange rates and have not considered technological factors such as digital payment. Second, we have verified the heterogeneity and mechanism pathways for the impact of digital payment on international trade status, providing robust literature support and policy recommendations for the development of digital payment and realization of its positive effects. Finally, we have constructed

two international trade networks that describe the different aspects of trade emphasis by using the trade proportion and trade intensity index as the network edges between the nodes. This represents a new research model, providing references for subsequent researchers studying international trade.

1.2. Literature review

The relevant literature in this paper can be roughly divided into three categories: the research on the international trade network, the research on the influencing factors of international trade, and the research on the effect of digital payment.

The first category is research on the international trade network. Research on the international trade network is commonly conducted by using social network analysis methods [10]. Three main types of literature categorize the construction of international trade networks based on the different edges between nodes. The first type of paper uses trade volume as the basis for constructing the network [11–13]. For example, Sun et al. [14] constructed a directed international agricultural trade network by using countries as nodes and agricultural export volumes as edges. They analyzed a country's import diversity and position in the international agricultural trade network by using network characteristic indicators such as weighted degree. The second type of literature involves constructing the international trade network by using trade volume that has undergone certain processing. For example, they judge whether there is a trade connection between two countries based on whether the trade volume has reached a threshold (4% of GDP), and then they construct an international trade network. Gray and Potter [15] have judged a country's trade partner diversity by using degree centrality and determined a country's centrality or marginality in the trade network by using eigenvector centrality. The third type of paper involves directly the existence of trade links to construct international trade networks [16,17]. For example, Baskaran et al. [13] used countries as nodes and the existence of trade links between two countries as the basis for constructing an unweighted international trade network. In general, social network analysis methods are a mature approach to studying international trade, but the specific construction of networks needs to be adjusted according to different research needs.

The second category is the research on the influencing factors of the international trade. Research has been conducted on the factors influencing international trade that involve multiple aspects, including social, political, and technological factors. In terms of social factors, Duan et al. [18] studied a global grain trade network and found that in addition to obvious factors such as economic development and resource endowment, cultural background differences such as language and religion also have an impact on international trade. Therefore, immigration is beneficial for strengthening trade connections between two countries, making the international trade network more tightly integrated [19]. In terms of political factors, capital control is a major obstacle to the development of international trade [20], while trade agreements are conducive to the development of international trade [21]. In terms of technological factors, in recent years, with the rapid development of digital technology, many scholars have conducted research in this area. Zhang et al. [22] believe that progress in communication technology can promote international trade by reducing transaction costs, improving efficiency, and regulating information asymmetry. Jiang and Jia [23] conducted more detailed research and revealed the promotional effect of digitization on digital service trade, while also pointing out the heterogeneity of this effect across countries with different development levels. Overall, scholars generally expect digitization to promote the development of international trade. However, current research on the impact of digital technology on international trade is still in its infancy. In particular, no scholars have studied

the impact of digital payments on international trade networks.

Finally, there is research on the effect of digital payment. Scholars' research on payment settlement has never stopped [24]. As an emerging and efficient payment method in recent years, some scholars have researched its impact [25]. A direct view is that digital payment has the effect of increasing consumer demand, and this effect is more significant in rural areas [26,27]. Furthermore, some scholars have further studied this effect and believe that digital payment will promote overspending while promoting consumption, and that the improvement of financial literacy can mitigate this effect [28]. In addition, digital payment can also play a positive role in the promotion of family medical care and improvement of residents' well-being [29,30]. At the same time, some scholars have called attention to the many risks that digital payment may bring while enjoying its dividends [31]. Overall, scholars' research on digital payment is mostly concentrated at the micro level and has not yet included the macro level.

To sum up, the impact of digital technology on international trade is gradually attracting attention. Digital payment is an important product of digital technology, but scholars have not yet focused on the role of digital payment in international trade. Therefore, it is necessary to explore in detail the impact of digital payment on international trade. On the one hand, it can enrich the research on the impact of digital technology on international trade; on the other hand, it can make up for the fact that current research on digital payment has not yet been conducted at reached the macro level.

The rest of this paper is structured as follows. The second section discusses is the construction of the international trade network. The third section describes the research scheme, which puts forward the basic assumptions about the impact of digital payment on international trade status, details the econometric test model, introduces the variables in the model, and explains the source of the data used. The fourth section presents the empirical results, that is, the main results of the empirical test and the analysis of the results. The fifth section presents the conclusion and policy implications of this article.

2. Construction of international trade network

We mainly investigated the changes in international trade status, while also considering the impact of international trade connections on the international trade status. To measure the international trade status and the intensity of international trade links of each country more accurately and effectively by using networks, we constructed weighted and unweighted international-focused trade networks. The commodity trade data used to construct the network comes from the International Trade Center. We used the data of 189 United Nations member states (after excluding four countries with missing data) for network construction, and the years are 2012–2020.

2.1. Construction of weighted international trade network

The weighted international trade network was constructed to study various countries' international trade status. The international trade status of a country is affected by the number of countries, specifically, the trade links and the trade volume among them. We comprehensively considered these two factors in the construction of the weighted international trade network. In this network, 189 countries were used as nodes, and the proportions of trade volume in the global trade volume between countries are used as the edges between nodes. The network can be represented by adjacency matrix **G**:

$$G = \begin{bmatrix} 0 & w_{12} & \cdots & w_{1n} \\ w_{21} & 0 & & w_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & 0 \end{bmatrix} \tag{1}$$

In Eq (1), w_{ij} represents the links between country i and country j, measured by the proportion of the total trade volume between country i and country j to the total international trade volume of the year. This measurement method will effectively eliminate the deviation between different years of international trade, giving the network characteristics horizontal and vertical comparability.

The weighted network's degree of centrality reflects a country's centrality in international trade. The formula for the degree of centrality is as follows:

$$degree_i = \frac{\sum_{j=1} a_{i,j} w_{i,j}}{n-1} \tag{2}$$

In Eq (2), $a_{i,j}$ represents the trade status between countries *i* and *j*. It is recorded as 1 if there is trade between country *i* and *j*, and otherwise as 0; *n* denotes the total number of countries. Table 1 lists the top 10 countries in terms of degree of centrality from 2012 to 2020:

Table 1. Top 10 countries in terms of weighted international trade network degree of centrality for 2012–2020.

RANK	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	USA	USA	USA	USA	USA	USA	USA	USA	CHN
2	CHN	CHN	CHN	CHN	CHN	CHN	CHN	CHN	USA
3	GER	GER	GER	GER	GER	GER	GER	GER	GER
4	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN
5	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA
6	NLD	UK	NLD	UK	UK	UK	NLD	NLD	NLD
7	UK	NLD	UK	Kr	NLD	NLD	UK	UK	UK
8	KR	KR	KR	NLD	KR	KR	KR	KR	KR
9	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA
10	CAN	CAN	CAN	CAN	CAN	CAN	MX	MX	MX

Note: CHN: China, GER: Germany, JPN: Japan, FRA: France, NLD: Netherlands, UK: United Kingdom, KR: Republic of Korea, ITA: Italy, CAN: Canada, MX: Mexico.

As can be seen in Table 1, the major trading countries in the world remained roughly unchanged from 2012 to 2020, forming an international trade pattern with diversified development of the USA, China, Japan, and European economies. It can be ascertained from the table that the weighted international trade network constructed in this study has a certain rationality and can accurately reflect the status of a country in international trade.

2.2. Construction of unweighted international trade network

In the existing literature, trade volume is usually used to measure the strength of trade links between two countries. However, this method has certain deviations. With this approach, countries

with smaller trade volumes will have no countries with which to construct close trade links, which is seriously inconsistent with the facts. This bias also exists if we study the strength of international trade links based on the weighted international trade network above. Therefore, we constructed an unweighted international trade network to detect the intensity of international trade links.

For the unweighted international trade network, we introduce the trade intensity index (TII) as the basis for measuring the intensity of trade links among countries.

The TII is an important tool to measure the closeness of trade links between trading partners. It is the ratio of a country's exports to a trading partner country to the country's total exports divided by the ratio of the trade partner's total imports to the world's total imports. The commonly used TII calculation formula is as follows:

$$TII_{i,j} = \frac{O_{i,j}/O_i}{I_j/I_w} \tag{3}$$

In Eq (3), $TII_{i,j}$ represents the TII between country i and country j, $O_{i,j}$ represents the total export value of country i to country j, O_i represents the total export value of country i, I_j represents the total import value of country j, and I_w represents the total world imports. It is generally believed that if $TII_{i,j} \geq 1$, it means that the trade relationship between the two countries is close, and otherwise, it means that the trade relationship between the two countries is not close.

According to Eq (3), we calculated the TII among countries. If the TII between the two countries reaches 1, a trade link is considered to exist between them; otherwise, there is no trade link between the two countries. Using the TII as a measure of trade links rather than directly using the trade volume method can more accurately reflect the strength of trade links between two countries. Finally, we chose to apply countries as nodes and the trade links between the two countries as the edges between nodes to build an unweighted international trade network. The construction method is similar to that shown in the weighted international trade network above. The degree of centrality of the network can reflect the overall trade links between a country and other countries in the trade network, that is, the strength of international trade links.

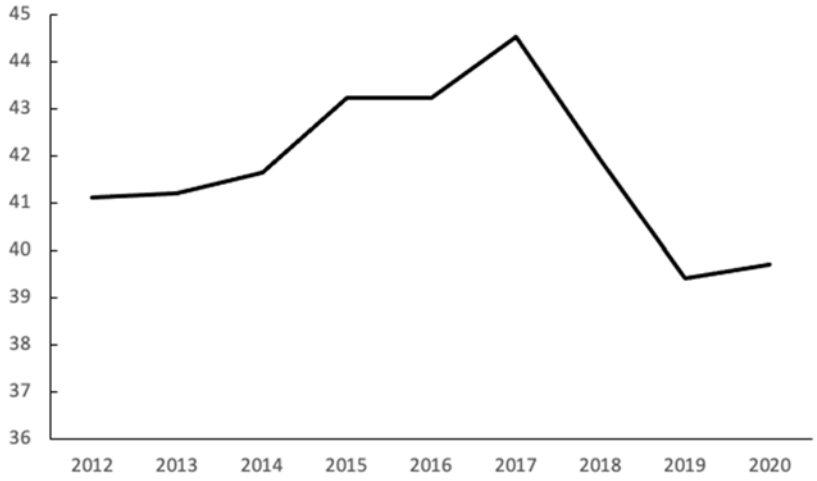

Figure 1. 2012–2020 changes in the average degree of centrality of the unweighted international trade network.

As is shown in Figure 1, the average degree of centrality of the unweighted international trade network generally exhibited a steady upward trend. However, it dropped sharply in 2018–2019 and then rebounded again in 2020. The characteristics shown in this figure reflect the changing trend of today's increasingly close international trade links. The decline in 2018 and 2019 may be due to the rise of global trade protectionism triggered by the Sino-U.S. trade war, resulting in weakening international trade links. In general, the development trend of the unweighted international trade network constructed in this study is more in line with reality, indicating that the network proposed in this paper has certain credibility and can be used for empirical research purposes.

3. Research scheme

3.1. Theoretical analysis and research hypotheses

Digital payments can affect the international trade status of various countries in the following three aspects. Firstly, digital payments have the advantages of low cost and a short settlement cycle, which can help import and export enterprises reduce transaction costs and exchange rate risks [32]. At the same time, this also means that countries with higher levels of digital payment development are more likely to gain competitive advantages in international trade, which helps to improve their international trade status. Secondly, digital payments provide more convenient payment settlement and foreign exchange transaction functions, which can help a country attract more foreign investment, thereby promoting the development of its international trade [33,34], and achieving the goal of improving its international trade status. Finally, digital payments impact the traditional international payment settlement system, which will inevitably lead to changes in the international trade pattern. Specifically, digital payments may promote the decentralization of global trade and increase the international trade participation of emerging market countries. In this process, countries with higher levels of digital payment development can quickly establish a sound digital payment system and apply it to international settlements, forming a trade group that is centered around their payment settlement system, which can improve their international trade status. Based on the above analysis, we put forward Hypothesis 1:

Hypothesis 1: Digital payments can improve the international trade status of a country.

The changes in international trade status are essentially changes in the trade connection status between countries. The larger the number of trading partners of a country and the closer its link with trading partners, the higher its position in international trade. Digital payments have changed the trade links between countries and thus improved the international trade status of some countries. On the one hand, digital payments provide convenient and low-cost international payment settlement methods, lower the threshold for enterprises in the country to participate in international trade, and provide possibilities for small- and medium-sized enterprises to participate in international trade. Such effects may provide spillover effects for trading partner countries. This can make the international trade connections between the country and other countries closer, thereby improving its international trade status. On the other hand, digital payments have promoted the development of e-commerce, creating large and well-known cross-border e-commerce platforms such as AliExpress and Shopee. These platforms have shaped a new form of international trade, gradually breaking down barriers between countries and moving towards borderless trade [35]. At the same time, the low threshold characteristic

of cross-border e-commerce has attracted more people to international trade [36], making international trade links even closer.

Furthermore, digital payments strengthen international trade connections by reducing barriers to cross-border fund flows. Before digital payments emerged, cross-border fund transfers usually required the help of foreign exchange accounts, which were considered more complicated and costly. With the development of cross-border digital payment platforms, cross-border fund transfers, especially small-amount transfers, have become very convenient. The reduction of barriers to cross-border fund flows shortens the settlement period of international trade, improves the efficiency of import and export trade, and attracts more enterprises to participate in import and export trade. This is of great help in promoting the development of import and export trade and improving the intensity of international trade connections between countries. Based on the above analysis, we propose Hypothesis 2:

Hypothesis 2: Digital payments strengthen a country's (region's) trade connections with other countries by reducing barriers to cross-border fund flows, thereby improving its international trade status.

Countries have varying degrees of trade openness, and the impact of digital payments on international trade status may vary as a result. Trade openness refers to the degree to which a country (region) is open to foreign markets. Objectively, countries with higher levels of trade openness are more likely to have higher levels of international trade development, while the opposite is true for countries with lower levels of trade openness. Therefore, digital payments have more opportunities for application in international trade in countries with high trade openness and that can play a more significant role in promoting international trade. In contrast, countries with low trade openness have more export restrictions, higher tariff levels, and stricter capital inflow and outflow controls [37]. The cross-border application platforms for digital payments are restricted, and the development of cross-border e-commerce is limited by many factors, making it difficult to significantly promote import and export trade. Subjectively, enterprises in countries with high trade openness have a stronger awareness of import and export trade and are more receptive to cross-border digital payments and cross-border e-commerce. Therefore, the promotional effect of digital payments on international trade is more likely to be effective in countries with higher trade openness. Over time, digital payments will further enhance the position of countries with high levels of trade openness in the international trade network. For countries with low levels of trade openness, the development of digital payments is more likely to increase their disadvantage in international trade. Based on the above analysis, we propose Hypothesis 3:

Hypothesis 3: The promotional effect of digital payments on international trade status presents as heterogeneous in countries with different levels of trade openness.

3.2. Model design and variable description

3.2.1. Model design

Given the multifaceted differences among different countries that cannot be fully quantified, as well as the different developmental environments for international trade over the years, we applied a two-way fixed effect model in the panel data model to examine the impact of digital payments on international trade status. This model has been widely applied in similar studies and has good practicality [38–42]. The specific form of the model is as follows:

$$wdeg_{i,t} = \alpha_0 + \alpha_1 dpay_{i,t} + \sum_{j=1}^{6} \delta_j \, Control_{j,i,t} + \mu_t + \sigma_i + \varepsilon_{i,t} \tag{4}$$

In Eq (4), i represents the country; t represents the year; $wdeg_{i,t}$ represents the international trade status; $dpay_{i,t}$ represents the developmental level of digital payment; $Control_{j,i,t}$ represents control variables; $\varepsilon_{i,t}$ represents random disturbances; μ_t and σ_i respectively represent the time-related fixed effect and individual fixed effect of the countries.

3.2.2. Variable description

Explained variables. The explained variable in this paper is the international trade status (*wdeg*), which is measured by the degree of centrality of the weighted international trade network constructed in the previous section. The higher the degree of centrality of a country in the weighted international trade network, the more central its position in the international trade network, indicating a higher international trade status (*wdeg*).

Table 2. Control variables.

Variable	Symbol	Calculation method	Explanation
Tariffs	tariff	Weighted average tariff rate	The level of tariffs affects the cost of trade among countries, which will impact the strength of international trade links and further affect the degree of international trade network centrality.
Inflation rate	inflation	GDP deflator	Severe inflation will lead to currency devaluation and seriously affect the import and export trade.
Employment rate	employ	Employment ratio of the population over 15 years old	The employment rate indirectly reflects the economic health of a country and has a specific impact on import and export trade.
Population density	lndensity	Number of people per square kilometer after logarithmic processing	The population is a resource that cannot be ignored in international trade. Whether for export or import, the population is always an essential factor.
Exchange rate volatility	exrate	The volatility of the official exchange rate (in USD)	A country's exchange rate fluctuations directly lead to changes in import and export costs, affecting the willingness of other countries to trade with it, thereby affecting the centrality of its in the international trade network.
Economic growth rate	growth	Volatility of GDP	Countries with fast economic growth are more likely to drive other countries' economic development in international trade and improve their degree of international trade network centrality.

Note: All data in the table were sourced from the World Bank database.

Core explanatory variable. The core explanatory variable of this study is the developmental level of digital payment (*dpay*), which is measured by the percentage of total electronic money payment in

GDP, that is, total electronic money payment × 100/GDP. The total amount of electronic money payment can more intuitively reflect the popularity of digital payment in a country. However, there are significant differences in the level of economic development and economic scale between countries, the total amount of electronic payment in each country is divided by the GDP of each country to obtain horizontally comparable data.

Control variables. Referring to previous studies and considering this study's needs, we selected tariffs (*tariff*), inflation rates (*inflation*), employment rates (*employ*), population density (*lndensity*), exchange rate volatility (*exrate*), and economic growth rate (*growth*) as control variables [43–45]. The measurement method is shown in Table 2.

3.3. Data sources and descriptive statistics

Due to the availability of the data related to digital payment, it was impossible use all countries in the international trade network as a research sample. The samples in the following analysis encompass the Committee of Payment and Market Infrastructure member countries of the Bank for International Settlements, amounting to 25 countries; the research years range from 2012 to 2020. All data used in this study were sourced from the International Trade Center, the Bank for International Settlements, the United Nations Conference on Trade and Development, and the World Bank. Descriptive statistics are shown in Table 3.

Table 3. Descriptive statistics for main variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
wdeg	225	5.738	5.359	0.593	23.638
dpay	225	24.042	18.185	2.460	121.380
tariff	225	3.126	2.237	0.050	13.780
inflation	225	3.720	7.364	-16.910	50.920
employ	225	61.047	6.402	47.980	73.360
lndensity	225	4.525	1.723	1.085	8.993
exrate	225	5.895	11.969	-12.990	71.380
growth	225	0.001	0.079	-0.340	0.230
ndeg	225	63.267	18.404	24.000	108.000
cropays	215	8.624	1.334	5.717	11.178
TOI	225	77.204	63.681	22.739	369.213

It can be ascertained from Table 3 that the data used in this study do not have singular values and can be used for empirical research. In Table 3, the maximum value of international trade status (*wdeg*) is 23.638, while the minimum value is only 0.593, indicating significant developmental differences among countries in terms of international trade status (*wdeg*). Meanwhile, the mean value is 5.738, which is closer to the minimum value, suggesting that the international trade status (*wdeg*) is generally low, and that only a few countries (regions) have significantly higher international trade status (*wdeg*) than others, which is consistent with the current international trade pattern. The data characteristics presented by the developmental level of digitalal payment (*dpay*) are similar to the international trade status (*wdeg)*, indicating that the development level of digital payment is quite different among the different countries, and that only a few countries have a relatively high level of

digital payment development.

4. Empirical results

4.1. Benchmark regression and robustness testing

To examine the effect of digital payment on international trade status, we regressed Eq (4) using standardized data from 25 countries for the period of 2012–2020. In addition, to address the potential endogeneity problems, we conducted robustness tests by using the two-step optimized gaussian mixture model estimation and two-stage least squares regression [46,47]. We applied the internet penetration rate, fixed broadband subscription rate, and cellular phone subscription rate as instrumental variables. The results are shown in Table 4.

Table 4. Results of benchmark regression.

	FE	2SLS	GMM
	(1)	(2)	(3)
	wdeg	wdeg	wdeg
dpay	0.118***	1.737***	1.763***
	(0.023)	(0.410)	(0.416)
cons	-0.001	-0.053	0.046
	(0.298)	(0.144)	(0.143)
Control variables	YES	YES	YES
Individual effect	YES	No	No
Time effect	YES	No	No
N	225	225	225
R^2	0.1244		

Note: '', '* *', and '* * *' represent significance levels of 10%, 5%, and 1%, respectively. The robust standard error is shown in parentheses. Due to space limitations, the detailed control variable coefficients can be found in the supplementary documents.

As is shown in Table 4, the development of digital payments significantly improves international trade status. In Table 4, column (1) shows the baseline regression results of this study, which examines the promotional effect of digital payments on international trade status (*wdeg*) in a two-way fixed effect model. The results indicate that a one-standard-deviation increase in the level of digital payment development (*dpay*) leads to a 0.118 standard deviation increase in international trade status (*wdeg*). This verifies Hypothesis 1 of this paper.

Columns (2) and (3) show the estimated results for two-stage least squares regression (2SLS) and two-step optimized GMM estimation, respectively. The results show that the promotional effect of digital payments on international trade status remains significant even after changing the regression model, indicating the robustness of this study's empirical results.

The popularity of digital payments worldwide as well as its quick application as an international trade settlement method in a short period is due to its convenience and low-cost characteristics. Digital payment utilizes modern information technology such as the Internet, which makes cross-border payment processes simpler and does not require cumbersome approval procedures. This means a

decrease in time cost and a reduction in exchange rate risk, which benefits cross-border trading enterprises in shortening trade cycles. In addition, according to the annual Global Payments Report by Fidelity National Information Services, digital payments are the preferred payment settlement method for cross-border e-commerce. This is because cross-border e-commerce typically operates on a B2C business model, and payment settlement speed and convenience are crucial, which digital payments can provide. Therefore, countries with high levels of digital payment development tend to have more developed cross-border e-commerce. In summary, the development of digital payments can strengthen a country's trade links with other countries and continuously enhance its international trade status during this process.

To further ensure the robustness of our empirical results, we added the natural resource rents as a percentage of GDP (*source*) and the growth rate of total household consumption (*consumption*) to the regression model as control variables. Consistent with the selection of the baseline regression model, individual and time effects have been included in the 2SLS and GMM models. The econometric results are shown in the following table:

Table 5. Results of robustness testing.

	FE	2SLS	GMM	2SLS	GMM
	(4)	(2)	(3)	(5)	(6)
	wdeg	wdeg	wdeg	wdeg	wdeg
dpay	0.139***	1.385***	1.409***	0.328***	0.328***
	(0.022)	(0.428)	(0.438)	(0.055)	(0.054)
cons	-0.540*	0.003	0.057	-0.760***	-0.727***
	(0.324)	(0.159)	(0.161)	(0.252)	(0.240)
Control variables	YES	YES	YES	YES	YES
Individual effect	Yes	No	No	Yes	Yes
Time effect	Yes	No	No	Yes	Yes
N	225	225	225	225	225
R^2	0.2262				

As shown in Table 5, after adding new control variables, the coefficient for the effect of digital payments on international trade status remains significantly positive. This indicates the robustness of the empirical results of this study.

4.2. Channel analysis

Based on the previous analysis, digital payments can improve the intensity of international trade links by reducing barriers to cross-border capital flows and ultimately enhancing international trade status. This is a chain-mediated effect. To verify whether this effect holds, we used the international trade linkage intensity (*ndeg)* introduced earlier and the logarithm of personal balance of payments on cross-border capital flows (*cropays*) from the United Nations Conference on Trade and Development as the mediator variables for regression. We used stepwise regression to verify the mediating effect; the model settings include Eq (4) and the following equations:

$$cropays_{i,t} = \beta_0 + \beta_1 dpay_{i,t} + \sum_{j=1}^{6} \delta_j \, Control_{j,i,t} + \mu_t + \sigma_i + \varepsilon_{i,t} \tag{5}$$

$$ndeg_{i,t} = \beta_2 + \beta_3 dpay_{i,t} + \sum_{j=1}^{6} \delta_j \, Control_{j,i,t} + \mu_t + \sigma_i + \varepsilon_{i,t} \tag{6}$$

$$wdeg_{i,t} = \beta_4 + \beta_5 ndeg_{i,t} + cropays_{i,t} + \sum_{j=1}^{6} \delta_j \, Control_{j,i,t} + \mu_t + \sigma_i + \varepsilon_{i,t} \tag{7}$$

$$wdeg_{i,t} = \beta_6 + \beta_7 dpay_{i,t} + cropays_{i,t} + ndeg_{i,t} + \sum_{j=1}^{6} \delta_j \, Control_{j,i,t} + \mu_t + \sigma_i + \varepsilon_{i,t} \tag{8}$$

The regression results are shown in the following table:

Table 6. Results of channel analysis.

	(1) wdeg	(2) cropays	(3) ndeg	(4) ndeg	(5) wdeg
dpay	0.118***	0.277***	0.251***	0.210***	0.068***
	(0.023)	(0.055)	(0.070)	(0.077)	(0.022)
cropays				0.167*	0.220***
				(0.098)	(0.028)
ndeg					0.145*
					(0.075)
cons	-0.001	0.534	-1.286	-1.344	-0.110
	(0.298)	(0.668)	(0.897)	(0.866)	(0.250)
Control variables	YES	YES	YES	YES	YES
Individual effect	YES	YES	YES	YES	YES
Time effect	YES	YES	YES	YES	YES
N	225	215	225	215	215
R^2	0.1244	0.1729	0.0960	0.1139	0.3588

According to Table 6, digital payments can improve the intensity of international trade links by reducing barriers to cross-border capital flows and ultimately enhancing international trade status. As shown in columns (2)–(5), for every one standard deviation increase in the level of digital payment development, the personal balance of payments on cross-border capital flows (*cropays*) increases by 0.277 standard deviation units, and the international trade linkage increases by 0.251 standard deviation units. At the same time, for every one standard deviation increase in the personal balance of payments on cross-border capital flows, the international trade linkage (*ndeg*) increases by 0.167 standard deviation units. This indicates that digital payments can reduce barriers to cross-border capital flows and thus enhance international trade linkage. For every one standard deviation increase in international trade linkage (*ndeg*), the international trade status (*wdeg*) increases by 0.145 standard deviation units. The conclusion validates Hypothesis 2 of this paper.

Here we will further elaborate on the impact of digital payments on international trade status. First of all, through technological innovation, digital payments create better conditions for cross-border capital flows and reduce barriers to such flows. On one hand, the reduction of barriers to cross-border capital flows is conducive to the import and export of goods and services between countries, which has a direct promotional effect on international trade. In cross-border transactions, in the past, buyers and sellers had to go through complex payment and settlement processes, during which they needed to rely on cross-border banks to achieve final payment and settlement, which required a certain level of professional knowledge from both parties. Digital payment, as a new payment settlement method, greatly simplifies the payment settlement process and reduces the difficulty of payment settlement. The digital payment platform is responsible for negotiating with banks, and both parties can achieve convenient foreign currency exchange, payment, receipt, and local currency exchange on the platform. Moreover, this process does not require a significant amount of transaction, providing great convenience for international trade in terms of payment and settlement processes and scale, while also contributing to the rise of cross-border retail. On the other hand, the decrease in barriers to cross-border capital flows creates a better environment for international investment, which often involves the export and import of technology and production factors, stimulating the development of international trade. This explains the strengthening effect of the weakening of cross-border payment barriers on international trade relations. In general, the development of digital payments in a country can effectively lower its barriers to capital flow and strengthen trade links with other countries, thereby enhancing its central position in international trade. Furthermore, countries with high levels of digital payment development have weaker barriers to capital flows between them, which increases the intensity of trade links between them and makes the global trade network more tightly connected.

4.3. Heterogeneity analysis

Based on the previous hypothesis, we divided the 25 sample countries into two groups according to the mean value of trade openness (*TOI*) of each country from 2012 to 2020; we also conducted group regression to explore whether the difference in trade openness will affect the impact of digital payment on the international trade status. The formula for calculating the degree of trade openness (*TOI*) is total import and export trade / total GDP. The measurement results are shown in Table 7.

According to Table 7, there is heterogeneity in the impact of digital payments on international trade status. In regions with high trade openness, the coefficient for the impact of digital payments on international trade status is significantly positive. Specifically, for each one standard deviation increase in the level of digital payment development (*dpay*), the international trade status (*wdeg*) increases by 0.165 standard deviation units. However, in regions with low trade openness, the impact of digital payments on international trade status is not significant and the coefficient is negative. This result validates Hypothesis 3 of this paper.

Based on the above conclusions, we believe that the insignificant promotional effect of digital payments on international trade status in countries with low trade openness is due to the competitiveness of international trade. International trade is a complementary process in terms of resources and a process of games between countries. International trade development varies globally. When new things emerge in international trade, countries with higher trade openness and more developed import and export trade will usually adopt them earlier. Therefore, the advantages of digital payments are better utilized in these countries, while their impact is limited in countries with low trade openness.

Table 7. Heterogeneity test results.

	High trade openness	Low trade openness
	(1) wdeg	(2) wdeg
dpay	0.165***	-0.090
	(4.940)	(-1.220)
cons	-0.759*	0.835**
	(-1.676)	(2.628)
Control variables	YES	YES
Individual effect	YES	YES
Time effect	YES	YES
N	117	108
R^2	0.2229	0.1858

In an international trade network that is either advancing or receding, such differences may lead to widening developmental gaps between countries. In addition, the degree of openness of foreign trade represents to some extent the degree of economic openness of a country, reflecting and affecting its inclusiveness. From a humanistic perspective, countries with higher trade openness often have higher inclusiveness. On the one hand, as an emerging payment method, digital payments are more likely to develop well in countries with greater inclusiveness. On the other hand, a highly inclusive environment contributes to digital payments playing a strongly promotional role in import and export trade. The impact of digital payments on international trade status is heterogeneous due to the comprehensive effects of economic development and various humanistic factors.

5. Conclusions

We constructed an international trade network and used network characteristics to measure the international trade status of countries. Based on this, panel data at the national level from 2012 to 2020 were used to examine the impact of digital payments on international trade status. The research results show that, first, the development of digital payments can effectively enhance a country's international trade status. Second, digital payments strengthen inter- and intra-country trade links by reducing barriers to cross-border capital flows, thereby enhancing international trade status. Third, there is heterogeneity in the impact of digital payments on international trade status in countries with different levels of trade openness. In countries with high trade openness, digital payments have a significant promotional effect on international trade status, while in countries with low trade openness, they have no significant effect, which is determined by the competitiveness of international trade.

Based on the above empirical research conclusions, we put forward the following policy recommendations, because the uncertainty of policies may lead to some negative consequences [48–50]. First, countries should improve the construction of digital payment infrastructure and create a good developmental environment for digital payment. This mainly includes two aspects: the development of digital technology and the follow-up of related equipment. On the one hand, countries should promote the development of digital payment technology, especially digital payment security technology, to promote the sustainable and safe development of digital payment. On the other hand, countries should

accelerate the construction of servers and the full coverage of network base stations to ensure that digital payments can be smoothly implemented within their borders. Second, countries should further improve the degree of foreign trade openness, create a better humanistic environment for the development of digital payment, and create more opportunities for its application. Digital payments will inevitably bring more innovative forms of national trade, which may involve areas that policies do not consider. The government should ensure that the country's level of foreign trade openness can meet the requirements for the development of digital payments. Finally, digital payment will reduce the barriers to the flow of cross-border funds, which will bring risks to the development of international trade. Therefore, countries should perfect relevant laws and regulations to guide the development of digital payment in the right direction; they should then provide effective legal support for digital payment to improve the degree of international trade network centrality and the strength of international trade links. In addition, as digital payment technology and blockchain technology mature, government-issued digital currencies and non-government-issued digital currencies will increasingly co-exist in the market, both of which have sparked much discussion [51–56]. The government should fulfill its regulatory responsibility for digital currencies issued by non-governments to avoid risks to economic development.

Use of AI tools declaration

The authors declare that they have not used artificial intelligence tools in the creation of this article.

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Conflict of interest

The authors declare that there is no conflict of interest.

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