EMERGING MARKETS FINANCE AND TRADE
https://doi.org/10.1080/1540496X.2023.2171725

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Can Export Market Diversification Mitigate Agricultural Export Volatility? A Trade Network Perspective

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ABSTRACT
Using the social network analysis (SNA) method to calculate the level of agricultural export market diversification in various countries, this study examined the impact of agricultural export market diversification on export volatility from the supply network perspective based on HS6-digit agricultural export data. We identified that the agricultural export market diversification significantly reduces the export volatility. Specifically, the effect of diversifying the export market of processed agricultural products in stabilizing export volatility is greater than that of primary agricultural products. The stabilizing effect of emerging markets and developing countries or regions is more evident than developed countries or regions. Moreover, the export market diversification can stabilize the volatility of agricultural exports through two mechanisms: increasing the international market share and extending the export duration.

KEYWORDS
Export market diversification; export volatility; agricultural exports; trade network

JEL
F14; Q17

1. Introduction

Since 2019, the global spread of the COVID-19 pandemic and geopolitical uncertainty has severely dampened confidence in international cooperation. International trade, the engine of global economic growth, had been declining, which seriously affects the process of global economic recovery. In global trade, the volatility in the growth of agricultural exports are particularly severe. Figure 1 exhibits that the volatility curve of the growth rate of world agricultural exports appeared six troughs between 1996 and 2020. The interval between the first three troughs was 4–6 years, the interval between the three troughs after 2009 was only 3–4 years. It reveals that the volatility of world agricultural export growth has become more frequent. Among them, the difference in growth rate for two consecutive years exceeded 20.00% twice. The difference between the growth rate of the world's total agricultural exports in 2009 and 2008 was 33.18%, and the difference between 2012 and 2011 was 22.54%. These two situations evidence that the economic crisis in 2008 and the overall slowdown of the world economic recovery in 2012 led to large volatilities in the growth rate of total world agricultural exports during 2008–2009 and 2011–2012. Increased export volatility discloses that trade is more vulnerable against a backdrop of economic uncertainty. Frequent volatility in export value will increase the uncertainty of exports, which will lead to distortions in the allocation of labor factors of export enterprises, increases in output fluctuations and the risk of export decision-making, further hindering the long-term development of export growth. Supply shocks can even trigger economic volatility through the "propagation effect" of the hub sector in the production network (Carvalho 2014) and the "cascading effect" of various sectors (Acemoglu et al. 2012). The volatility of agricultural exports is even more so. The frequent volatility in international agricultural supply will not only affect global agricultural prices, but also affect the food security of some countries (Zhang et al. 2022). Take grain export as an

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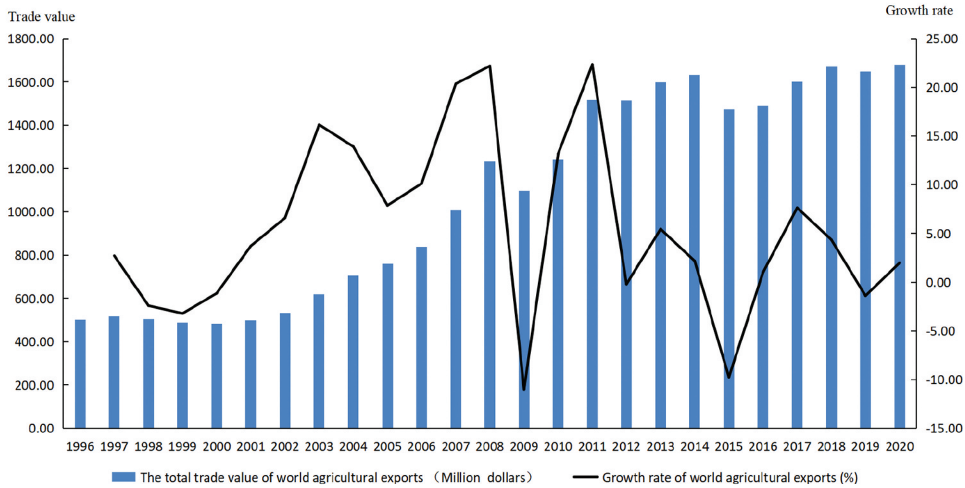

Figure 1. World agricultural export trade value and growth rate between 1996 and 2020. *Source*: The data in the figure is calculated by the author based on the CEPII-BACI database.

example, under the impact of the COVID-19 pandemic, many prominent grain-producing countries have announced export bans, export quotas, and other restrictions on grain. Some agricultural supply chains in the international grain market have been interrupted, and agricultural exports have significant volatility. Influenced by the COVID-19 pandemic, the FAO grain price index hit a new high in nine years in October 2021.[1] Russia and Ukraine are essential countries in global grain production and export. The conflict between Russia and Ukraine has further exacerbated the volatility of international food supply, resulting in food shortages in Egypt, Turkey, Iran, and other countries highly dependent on food imports from Russia and Ukraine. The impact of the COVID-19 epidemic, local conflicts, and other risks on the global food supply market have triggered concerns about food security in agricultural demand countries. Due to the vulnerability of agriculture and the importance of a stable supply of international agricultural products, when facing the impact of external risks such as the COVID-19 epidemic and local conflicts, it is of great importance to smooth the sharp volatility of agricultural exports, promote the steady growth of agricultural exports, and build a balanced pattern of global agricultural product supply chain. This is an important focus to achieve the security of global agricultural product supply, and it is also an issue closely concerned by policymakers and scholars in various countries.

The literature related to this study mainly includes three aspects. First, regarding the measurement method of export volatility, the existing literature is relatively uniform and mainly uses the variance of export growth rate to measure export volatility (Di Giovanni, Levchenko, and Mejean 2014; Vannoorenberghe 2012; Vannoorenberghe, Wang, and Yu 2016; Zhang and Sun 2018). Second, in terms of research on the influencing factors of export volatility, previous literature has mainly analyzed the impact of export diversification (Vannoorenberghe, Wang, and Yu 2016), export concentration (Tseng 2017), trade policy uncertainty (Chen and Zhao 2021), financing constraints (Meng et al. 2021), and other factors on export volatility. Some researchers have evidenced that diversifying export markets and reducing export concentration can effectively diversify export risks, reducing export volatility (Garcia-Vega, Guariglia, and Spaliara 2012; Hirsch and Lev 1971), but other studies have come to different conclusions. Love (1979) studied the impact of export concentration on export volatility with 52 developing countries as samples and revealed that the improvement of export concentration significantly promoted the increase of export stability. Lu and Li (2018) found that the impact of market diversification on export volatility presents an inverted "U"-shaped dynamic characteristic. That is, at the initial stage of the implementation of the export market diversification strategy, the uncertainty of market demand faced by enterprises will increase due to the increase of shock sources in new markets, leading to an increase in export volatility. However, when the export market diversification reaches a critical level, the function of the export market diversification strategy to disperse risks begins to appear, gradually reducing the market uncertainty and leading to the decline of export volatility. The conclusion is still valid after using instrumental variable estimation. Vannoorenberghe, Wang, and Yu (2016) used the export data of China's enterprises between 2000 and 2006 to study the firm heterogeneity in which market diversification affects export volatility. The results of the instrumental variable estimation determined that the export market diversification of smaller firms significantly promoted export volatility, while the market diversification of larger firms significantly suppressed the export volatility. Besides the firm heterogeneity, there is also country heterogeneity in the impact of export market diversification on export volatility. Cede et al. (2018) took the Central and Eastern European countries as a sample and revealed that the diversification of export markets in developing countries can significantly reduce export volatility, but the effect of developed countries on suppressing export volatility is not significant.

Third, the literature on studying export volatility from the perspective of trade networks. With economic globalization, global trade is interconnecting to form a network, which has also prompted researchers to measure market diversification, concentration, and other indicators from trade networks. Among them, the disparity of trade network nodes (*Disparity*) reflects the concentration degree of a country's exports and the dispersion degree of markets. The smaller the value, the more dispersed the destination market of a country's exports, and the more equal the export share to each destination market (Ma, Ren, and Wu 2016), and the higher the level of export market diversification. Zhang and Sun (2017) used the export data of China Customs between 2000 and 2006 at the level of "enterprise-product-destination" to study the impact of demand network concentration on the export volatility of Chinese enterprises. They identified that enterprises with low demand network concentration have high-risk diversification ability, which can effectively alleviate the volatility of its exports. Kramarz, Martin, and Mejean (2020) found that the increase in export concentration will make the risks faced by enterprises in the trade network unable to diversify, which will lead to export volatility.

Based on the above literature review, we found deficiencies in the existing literature and further elaborate on the marginal contribution of this study. First, the studies from the perspective of trade network are sparse in the existing literature. Only a few papers mainly focus on the perspective of demand network and the existing literature lacks research on the impact of export market diversification on export volatility from the perspective of the supply network. This paper supplements the existing literature in this field. We construct a world supply trade network and study the impact of export market diversification on export volatility from the perspective of supply networks. We further explore product heterogeneity and country heterogeneity on this basis. Second, for the index measurement of diversification and concentration, the previous literature mainly considers the numbers of export markets (or product types) and trade shares, respectively. There is a lack of a comprehensive index including the numbers of export markets and the trade shares of exports to various destinations to study its impact on export volatility. To solve this problem, we calculate the node disparity index (*Disparity*) based on the supply network. This index will comprehensively consider the number of export markets and the market shares of exports to various destinations. It can present the level of each country's export market diversification more reasonably and comprehensively. Third, the existing literature has not reached a consistent conclusion on the impact of market diversification and export concentration on export volatility, and it mainly focuses on the export of manufacturing industry or the overall export of all industries. The literature on the impact of export diversification on export volatility from the perspective of agriculture is relatively scarce. Based on this, this study first deduces the conclusion that export diversification can stabilize export volatility by building a theoretical model. Then take the agricultural exports of countries worldwide as an example to verify the impact of agricultural export market diversification on export volatility. The data uses HS6-digit agricultural products to more carefully reflect the impact of the product level. We further explore the differences between the effect of export market diversification of primary agricultural products and processed agricultural products on export trade volatility. Fourth, the existing literature lacks the exploration of the impact mechanism when studying whether export market diversification is conducive to stabilizing export volatility. The internal mechanism of diversification to suppress export volatility is still unclear. Our exploration of the impact mechanism makes up for the deficiency of the existing literature. Today, the COVID-19 epidemic has repeatedly delayed and intensified geopolitical conflicts, natural disasters have frequently occurred, and other uncertain risks are superimposed. Our research based on the perspective of trade networks provides theoretical support and decision making reference for agricultural-producing countries to build a diversified supply chain of agricultural products, disperse export risks and ensure the security of international agricultural product supply. At the same time, it provides experience for the global agricultural product market to reduce the risk of supply chain interruption and deal with the threat to food security.

The rest of the paper is organized as follows. Section 2 outlines the theoretical mechanism and research hypothesis. Section 3 presents data and empirical strategy. Section 4 provides our main empirical results. Section 5 is further analysis. Section 6 offers conclusion and policy implications.

2. Theoretical Mechanism and Research Hypothesis

2.1. Theoretical Model Framework

Referring to the method of Herskovic et al. (2020) in studying the volatility of firm sales, we decompose the export growth rate $g^n_{i,t+1}$ of product n in country i as follows:

$$g^n_{i,t+1} = \varepsilon^n_{i,t+1} + \lambda \sum\nolimits_{j=1}^{J} w^n_{ijt} g^n_{j,t+1} + \mu^n_g \tag{1}$$

where $\varepsilon^n_{i,t+1}$ is the production technology factor that affects the export growth rate of product n in country i. $\lambda \in [0, 1)$ is the decay rate of shock conduction in the demand network (estimated over the full sample by SMM moment estimation). j is the importing country. w^n_{ijt} is the proportion of product n exported from country i to country j in the total export trade of product n from country i in year t. $g^n_{j,t+1}$ is the growth rate of country $j's$ demand for product n in country i. μ^n_g are other factors that affect the export growth rate of product n in country i that do not change with time. Let $\mathbf{W}^n_{it}$ be a matrix composed of w^n_{ijt}, then the growth rate of export value can be presented in vector form as follows:

$$\mathbf{g}^n_{i,t+1} = \varepsilon^n_{i,t+1} + \lambda \mathbf{W}^n_{it} \mathbf{g}^n_{i,t+1} + \mu^n_g \tag{2}$$

Simplifying the Equation (2), the Equation (3) of the export growth rate can be given:

$$\mathbf{g}^n_{i,t+1} = \left(\mathbf{I} - \lambda \mathbf{W}^n_{it}\right)^{-1} \left(\varepsilon^n_{i,t+1} + \mu^n_g\right) \tag{3}$$

where $\left(\mathbf{I} - \lambda \mathbf{W}^n_{it}\right)^{-1}$ is the Leontief inverse matrix, which can be expanded according to the summation formula of the proportional series, thus we can get: $\left(\mathbf{I} - \lambda \mathbf{W}^n_{it}\right)^{-1} = \mathbf{I} + \lambda \mathbf{W}^n_{it} + \lambda^2 \mathbf{W}^{n2}_{it} + \lambda^3 \mathbf{W}^{n3}_{it} + \cdots \lambda^n \mathbf{W}^{nn}_{it} = \mathbf{I} + \lambda \mathbf{W}^n_{it} \frac{1-\left(\lambda \mathbf{W}^n_{it}\right)^n}{1-\lambda \mathbf{W}^n_{it}} \approx \mathbf{I} + \lambda \mathbf{W}^n_{it}$, substituting it into Equation (3), the export growth rate can be transformed into: $\mathbf{g}^n_{i,t+1} = \left(\mathbf{I} + \lambda \mathbf{W}^n_{it}\right) \left(\varepsilon^n_{i,t+1} + \mu^n_g\right)$. When the export share ($\mathbf{W}^n_{it}$) remains stable, the export volatility can be presented by the variance of the export growth rate:

$$var\left(\mathbf{g}^n_{i,t+1}\right) = var\left[\left(\mathbf{I} + \lambda \mathbf{W}^n_{it}\right) \left(\varepsilon^n_{i,t+1} + \mu^n_g\right)\right] \tag{4}$$

Since $\mathbf{W}^n_{it}$ remains constant while the export share remains stable, and $\left(\mathbf{I} + \lambda \mathbf{W}^n_{it}\right)$ is constant. Consequently, Equation (4) can be simplified as:

$$var\left(\mathbf{g}^n_{i,t+1}\right) = \left(\mathbf{I} + \lambda \mathbf{W}^n_{it}\right)^2 var\left(\varepsilon^n_{i,t+1} + \mu^n_g\right) \tag{5}$$

Since μ_g^n is a time-invariant constant, it exists: $var\left(\varepsilon_{i,t+1}^n + \mu_g^n\right) = var\left(\varepsilon_{i,t+1}^n\right) = \sigma_{in\varepsilon}^2$, substituting it into Equation (5) gives:

$$var\left(\mathbf{g}_{i,t+1}^n\right) = \left(\mathbf{I} + \lambda \mathbf{W}_{it}^n\right)^2 var\left(\varepsilon_{i,t+1}^n + \mu_g^n\right) = \sigma_{in\varepsilon}^2 \left(\mathbf{I} + \lambda \mathbf{W}_{it}^n\right)^2 \tag{6}$$

where $\left(\mathbf{I} + \lambda \mathbf{W}_{it}^n\right)^2$ means that each element in the matrix is squared, and the relational formula of the matrix (6) corresponding to each variable is:

$$var\left(g_{i,t+1}^n\right) = \sigma_{in\varepsilon}^2 \left(1 + \lambda^2 W_{it}^{n^2}\right) \tag{7}$$

Since $W_{it}^{n\,2} = \sum_{j=1}^{J} w_{ijt}^{n\,2} = \sum_{j=1}^{J} \left(S_{ijt}^n / S_{it}^n\right)^2$, where S_{ijt}^n is the trade value of product n exported from country i to country j in year t, and S_{it}^n is the trade value of product n exported from country i to the world in year t. Equation (7) can be expressed as:

$$var\left(g_{i,t+1}^n\right) = \sigma_{in\varepsilon}^2 \left[1 + \lambda^2 \sum_{j=1}^{J} \left(S_{ijt}^n / S_{it}^n\right)^2\right] \tag{8}$$

It can be seen from Equation (8) that the decline of $\sum_{j=1}^{J} \left(S_{ijt}^n / S_{it}^n\right)^2$ means that the share of exports to each destination market in the total exports of country i is gradually distributed evenly. That is, the export concentration is reduced, which is conducive to the diversification of export risks and further leads to the decline of export volatility.

Referring to Ma, Ren, and Wu (2016), we build the network node disparity index (*Disparity*) to measure the diversification level of the export market. The specific calculation formula is:

$$Disparity_{it}^n = \frac{(N_{it} - 1) \sum_j \left(S_{ijt}^n / S_{it}^n\right)^2 - 1}{N_{it} - 2} \tag{9}$$

where N_{it} is the number of export markets of country i in the trade network in year t. The lower the *Disparity* value, the more equal the share (S_{ijtn}/S_{itn}) of each destination market in the export of country i, indicating the higher the level of export diversification.

Substituting Equation (9) into Equation (8), the relational formula between the variance of the export growth rate and the *Disparity* can be given:

$$var\left(g_{i,t+1}^n\right) = \sigma_{in\varepsilon}^2 \left[1 + \lambda^2 \frac{Disparity_{it}^n \times (N_{it} - 2) + 1}{N_{it} - 1}\right] \tag{10}$$

Equation (10) indicates that the reduction of *Disparity*, namely the improvement of the diversification level of the export market, will lead to the decline of export volatility. The internal reason is that the decline of export concentration is conducive to spreading export risks and reducing the probability of export interruption when facing external risk shocks, so as to restrain export volatility.

Based on the model deduction results as we discussed previously, we propose Hypothesis 1

Hypothesis 1: Improving the diversification level of a country's export market will lead to a decline in export volatility.

2.2. The Mechanism of Export Market Diversification Affecting Export Volatility

Some researchers have evidenced that implementing market diversification strategy can increase the international market share of export products (Mohd and Zakariah 1993; Sun 2016). Through the export diversification strategy, a country gradually integrates into the supply chains and industrial chains of various importing countries, which enhances the importing country's demand preference and trade dependence on the exporting country to increase the international market share of the exporting country's products. The increase in the international market share indicates that the exporting country's product supply capacity is enhanced. It can meet the trade needs of the importing country, thereby improving export stability and reducing export volatility. Based on the conclusion as discussed, this paper proposes Hypothesis 2:

Hypothesis 2: Export market diversification restrains export volatility by increasing the international market share.

There is a "self-selection effect" in the export decision-making process of enterprises choosing whether to enter a new market (Melitz 2003). Firms with high productivity can enter new markets, while firms with low productivity exit the market (Alvarez and Lopez 2002; Bernard et al. 2007; Melitz and Ottaviano 2008). Due to the "redistribution effect," the average productivity of exporting firms increases (Feenstra 2015; Melitz 2003). Enterprises with high productivity have more advantages in terms of production scale and R&D capabilities. They can better resist trade risks in the international market, thereby extending the duration of their exports (Bekes and Murakozy 2012; Esteve-Perez, Requena-Silvente, and Pallardo-Lopez 2013; Gorg, Kneller, and Murakozy 2012), making the trade relationship between supply and demand more stable, and helping reduce export volatility. Moreover, enterprises can avoid export risks brought by a single market by choosing to export to more destination markets and reducing export concentration (Hericourt and Nedoncelle 2018; Hummels and Klenow 2005). Through the "risk diversification effect," the risk probability of enterprises' export interruption can be reduced, and the export duration can be prolonged, thereby enhancing the stability of trade relations and reducing export volatility caused by the interruption of trade relations. Based on this, this paper proposes Hypothesis 3:

Hypothesis 3: Export market diversification reduces export volatility by extending the export duration.

3. Data and Empirical Strategy

3.1. Data

This study examines the impact of export market diversification on export volatility by taking agricultural exports as an example. Based on the CEPII-BACI database, we calculated the value of HS6-digit agricultural export market diversification and export volatility of various countries or regions worldwide from 1996 to 2020. Deleting the samples with missing data, we retained sample data of 179 countries and regions,[2] which account for 96.47% of the total export of world agricultural products and are highly representative.

This paper draws a scatter plot of the relationship between the HS6-digit agricultural export volatility level (*Volatility*) in the world from 1996 to 2020 and the export markets diversification measured by node disparity (*Disparity*). As shown in Figure 2, the slope of the fitting line is positive, indicating that with the increase of the value of node disparity, the volatility range of agricultural exports increases. This conclusion reveals that the higher the level of a country's agricultural export market diversification, the lower export volatility. The scatter plot supports the negative impact of agricultural export market diversification on export volatility at the data statistics level. More rigorous econometric models will be used to further verify and analyze the causality.

3.2. Empirical Strategy

3.2.1. Benchmark Regression Model

Based on the previous theoretical hypothesis 1, improving the diversification level of a country's export market will lead to a decline in export volatility. We set an estimation model shown as Equation (11), and use ordinary least squares (OLS) to estimate it.

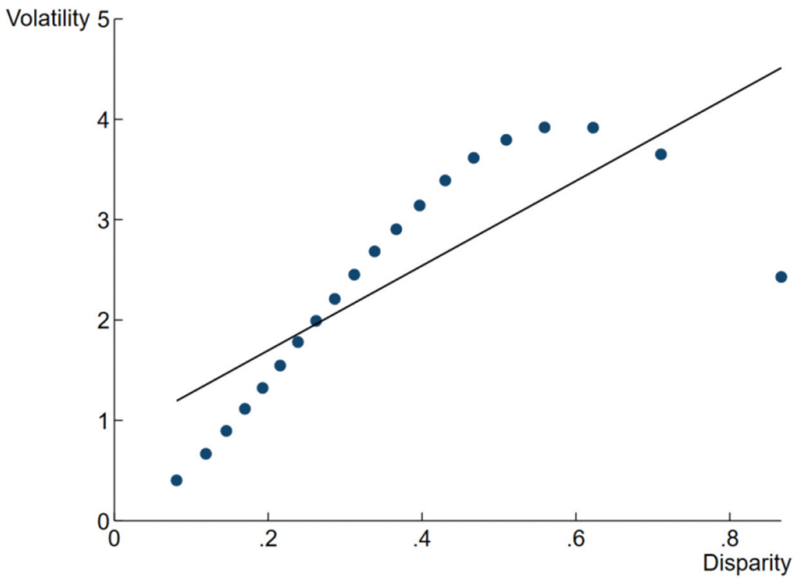

Figure 2. Correlation between export market diversification and export volatility. *Source*: The data in the figure is calculated by the author based on the CEPII-BACI database. Volatility is measured by the variance of the growth rate of agricultural exports value for five consecutive years. The calculation formula of node disparity will be explained later.

$$Volatility_{int} = \alpha_0 + \alpha_1 Disparity_{int} + \beta CV_{it} + \lambda_t + \mu_i + \gamma_n + \varepsilon_{int} \quad (11)$$

where i represents the country, n represents the product, t represents the year, and the dependent variable $Volatility_{int}$ is the measure of the trade value volatility of the product n exported by the i country in year t. The independent variable is export market diversification, measured by node $Disparity_{int}$. CV_{it} is the control variables. λ_t, μ_i, and γ_n denote the fixed effects of year, country, and product, respectively. ε_{int} is the random disturbance term.

3.2.2. Variables

3.2.2.1. Dependent variable.
Volatility level of export trade value. To measure the volatility of export trade value, this study refers to the calculation method of Vannoorenberghe, Wang, and Yu (2016), and uses the variance of export growth rate to describe the export volatility, as follows:

$$Volatility_{int} = \sum\nolimits_t \left(g_{int} - \frac{1}{T} \sum\nolimits_t g_{int} \right)^2 \quad (12)$$

where $Volatility_{int}$ represents the level of export volatility. The larger the value, the greater the fluctuation range of the country's export growth rate and the lower the export stability. T represents the sample period span. This study refers to the moving window method (Zhang and Sun 2017) and selects the sample period span as 5 years. We calculate the volatility level of agricultural exports of various countries in 1997–2001, 1998–2002, . . ., 2016–2020, and integrate the above-mentioned cross-sectional data into panel data of the volatility of agricultural exports of various countries in 2001–2020. g_{int} represents the export growth rate of product n in country i from year $t-1$ to year T. The calculation method of g_{int} (Bricongne et al. 2012) is as follows:

$$g_{\mathrm{int}} = \frac{x_{\mathrm{int}} - x_{\mathrm{int}-1}}{(x_{\mathrm{int}} + x_{\mathrm{int}-1})/2} \quad (13)$$

where x_{int} is the trade value of product n exported by country i in year t. The advantage of using the midpoint growth rate method to estimate the export growth rate is that the rate of change is bounded and symmetrical to zero.

3.2.2.2. Independent variable. Export market diversification. In the world agricultural trade network, the countries participating in the trade can be regarded as "nodes," the trade relationship between the two countries is regarded as the "edge" connecting these two "nodes." The export trade value is the "weight" of the directional "edge," and the three constitute a directional weighted trade network. For the world agricultural trade network, node disparity reflects the characteristics of a country's agricultural export markets dispersion degree and export share concentration degree. Regarding the construction and calculation of the export market diversification index, this study refers to the node disparity index constructed by Ma, Ren, and Wu (2016) to measure the level of the node export market diversification. The specific calculation methods are as follows:

$$Disparity_{itn} = \frac{(N_{it} - 1)\sum_j \left(S_{ijtn}/S_{itn}\right)^2 - 1}{N_{it} - 2} \tag{14}$$

where i is the exporting country, j is the importing country, n is the agricultural product, t is the year, and n is the number of nodes (countries) in the export trade network. S_{ijtn} is the trade value of product n exported by country i to country j in year t. S_{itn} is the total trade value of product n exported by country i in year t. If the weight (S_{ijtn}/S_{itn}) of the import of n products from country i in each destination market to the total trade of n products exported from country i in that year is not much different, and the distribution of the shares of each market is relatively uniform, the $Disparity_{itn}$ value is close to 0. If there is only one destination market for the export of country i, namely $j = 1$, the value of $Disparity_{itn}$ is 1. The smaller the value of node disparity, the more the number of export markets in a country, the lower the export concentration, namely the higher the level of export market diversification.

3.2.2.3. Control variables. **Product-level variables include**: (1) Revealed comparative advantage *(RCA)*, which measures the competitiveness of a certain product of a country in the world market, and its calculation formula is: $RCA_{itn} = \left(S_{itn}/\sum_n S_{itn}\right)/\left(\sum_i S_{itn}/\sum_i \sum_n S_{itn}\right)$, where i represents the exporting country, n represents the exported product, t represents the year, S_{itn} represents the trade value of country i exporting n product in year t. The greater the RCA of product n of country i, the higher the competitiveness of product n of country i in the world market. (2) Product export share (*Share*) is measured by the proportion of a country's export of a certain product in the country's total export. **Country-level variables include**: (1) Economic openness (*Openness*), which is measured by the proportion of net foreign investment inflows to the country's GDP (Ahmed and Suardi 2009). The larger the proportion, the higher the country's economic openness. (2) *Exchange rate fluctuations* are measured by the real effective exchange rate index. (3). The *Inflation rate* is measured by the consumer price index.

The HS6-digit agricultural export data from 1996 to 2020 used in this paper are from the CEPII-BACI database. The number of nodes (countries) in the agricultural trade network is also calculated based on the original data of the CEPII-BACI database. The data on GDP, net inflow of foreign investment, real effective exchange rate index, and inflation rate in each country over the years are all from the World Bank database. The 777 kinds of agricultural products involved in this study are those covered by the WTO Agreement on Agriculture. The descriptive statistics of each variable are shown in Table 1.

Table 1. Variable descriptive statistics.

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Volatility	590550	2.1702	2.6682	0.0001	19.1131
Disparity	590550	0.3530	0.2031	0.0101	1.0000
RCA	590550	6.0738	258.6643	3.99e-08	112993.1000
Share	590550	0.0006	0.0061	3.15e-12	0.7278
Openness	590550	0.0589	0.1732	−0.5500	4.8757
Exchange rate fluctuations	590550	98.6395	12.3519	55.3232	296.3053
Inflation rate	590550	3.1887	4.2650	−4.4781	359.9366

Source: Authors' calculation.

4. Empirical Results

4.1. Benchmark Regression

Based on the benchmark regression model (11), this paper takes the export of agricultural products from various countries or regions as an example to empirically study the impact of a country's export market diversification on export volatility. First, we conduct OLS estimate. And in order to solve the endogeneity problem that may exist in the OLS estimation results, then we introduce instrumental variables (IV) and use two stage least squares (2SLS) to estimate model (11). The benchmark regression results are shown in Table 2. In addition, this paper uses IV estimation in robustness checks, heterogeneity analysis, and further analysis to reduce estimation bias caused by endogeneity problems.

Column (1) of Table 2 shows the results of OLS regression. It can be seen that the *Disparity* coefficient is significantly positive. Namely, the rise of the *Disparity* level will lead to a significant increase in export volatility. Since the smaller the *Disparity* value, the higher the level of the export market diversification, the benchmark regression results reveal that: the improvement of the level of

Table 2. Benchmark regression results.

	(1)	(2)
	OLS	2SLS
Panel A. Second-stage regression. Dependent Variable: ***Volatility***		
Disparity	3.0502***	5.5398***
	(0.0825)	(0.2431)
RCA	−0.0001**	−0.0001**
	(0.0000)	(0.0000)
Share	−29.4338***	−25.7256***
	(4.7609)	(4.5174)
Openness	−0.0663**	−0.0773**
	(0.0295)	(0.0305)
Exchange rate fluctuations	0.0016***	0.0020***
	(0.0005)	(0.0005)
Inflation rate	0.0056***	0.0077***
	(0.0015)	(0.0018)
Year fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Product fixed effects	Yes	Yes
Observations	590550	584684
Kleibergen-Paap rk Wald F statistic		1200.6260
Panel B. First-stage regression. Dependent Variable: ***Disparity***		
Mean of other products disparity		0.5101***
		(0.0140)
Observations		584684
First stage F statistic		1319.1600

Note: Robust standard errors in parentheses are clustered at the product level. The *, **, and *** superscripts indicate significance at the 10%, 5% and 1% levels, respectively.

agricultural export market diversification can significantly reduce export volatility. This estimation result is consistent with the previous theoretical model deduction result, which proves that Hypothesis 1 holds. The reason is that the diversification of trade partners will reduce a country's dependence on specific trade relations and enhance its ability to diversify export risks (Chen and Zhao 2021), thus reducing agricultural export volatility. Therefore, when faced with external risks, the diversification of export markets of agricultural suppliers can effectively mitigate agricultural export volatility by avoiding the export markets with more significant risks and diversifying export risks among partner countries. This will further promote the steady growth of agricultural exports, ensure the security of the international agricultural supply chain, and reduce the threat of food security caused by the interruption of the agricultural supply chain.

In the estimation of econometric models, endogeneity problems can make estimation results biased and inconsistent. Although we have controlled for other important variables affecting the relationship between export market diversification and export volatility, it is possible that some important independent variables have been missed. In addition, there may be reverse causality between export market diversification and export volatility, which can also bias the estimates. In order to deal with the endogeneity problem, this study refers to Liu and Qi (2021), who uses the export diversification index of other firms in the same industry as the instrumental variable of export diversification. We select other HS6-digit agricultural products at the HS2-digit agricultural products level and use their mean value of the *Disparity* (*Mean of other products disparity*) as the instrumental variable. The selection is based on: The instrumental variable must be related to the independent variable and not related to the residual. First, because of the high similarity of each product in HS2-digit agricultural products, for a certain HS6-digit agricultural product, the smaller the mean value of *Disparity* of other HS6-digit agricultural products, the higher the level of export market diversification of these products, which will accumulate more export experience and market information for this certain HS6-digit agricultural product and is more conducive to promoting the market diversification level of this HS6-digit agricultural product. This meets the correlation condition of the instrumental variables. Second, the mean value of *Disparity of* other HS6-digit agricultural products will not directly affect the export volatility of this HS6-digit agricultural product, which meets the exogenous condition of the instrumental variables.

Column (2) of Table 2 shows the IV regression results. The results show that the coefficient of *Disparity* is consistent with the OLS estimation and is significant at the 1% level. It reveals that the improvement of the market diversification level of the agricultural export significantly reduces the export volatility, which verifies hypothesis 1 again. Kleibergen Paap rk Wald F statistic is significantly greater than the critical value (16.38) of the Stock-Yogo test at the 10% level, indicating no problem with the weak instrumental variable. *Mean of other products disparity* passed the significance test at the level of 1%, and the F statistic in the first stage was far greater than the empirical test value (10), which again significantly ruled out the problem of weak instrumental variables. The above results evidence that the selection of the instrumental variable is reasonable.

4.2. Robustness Checks

First, we replace measures of export market diversification. We use the Herfindahl Index (*HHI*) instead of node *Disparity*. The *HHI* measures the level of export concentration from the perspective of the proportion of product export. The larger the value, the higher the level of export concentration and the lower the level of the export market diversification. The formula for the *HHI* is as follows:

$$HHI_{it}^{n} = W_{it}^{n}2 = \sum\nolimits_{j=1}^{J} w_{ijt}^{n}2 = \sum \left(\frac{S_{ijt}^{n}}{S_{it}^{n}}\right)^{2} \tag{15}$$

where S_{ijt}^{n} is the trade value of product n exported from country i to country j in year t, and S_{it}^{n} is the trade value of product n exported from country i to the world in year t. The meaning of *HHI* is the same as the node *Disparity* used in the previous article. The smaller the value of the two, the higher the level of the node (country) export market diversification.

Column (1) of Table 3 presents the robustness test results of using *HHI* to replace node *Disparity*. The results evidence that the coefficient of *HHI* is significantly positive, indicating that the improvement of export concentration of agricultural products in a country will lead to an increase in export volatility, namely the agricultural export market diversification is conducive to reducing the export volatility. The improvement of a country's export concentration level will lead to the simplification of its export market. The only single market cannot effectively disperse export risks when facing external risks such as demand shocks, leading to increased export volatility. The estimated result is consistent with the benchmark test result, which verifies the robustness of the benchmark regression.

Second, we substitute measures of export volatility. We use the *Absolute value of export growth rate* of each product over the years and the variance of the export growth rate for three consecutive years (*Volatility-3 years*) to measure the level of export volatility of each agricultural product. The greater the absolute value of export growth rate of each product, the higher the volatility level of its export. The dependent variable in column (2) of Table 3 is the *Absolute value of export growth rate*, each variable is the data of the past years, and the moving average is not used. From column (2) of Table 3, it can be seen that *Disparity* has a significant positive impact on export volatility. Namely, the diversification of the agricultural product export market has significantly reduced the volatility of agricultural product export. The dependent variable in column (3) of Table 3 is the variance of the export growth rate for three consecutive years (*Volatility-3 years*), capturing shorter term fluctuations, and the treatment of each variable is consistent with the benchmark regression. The regression results in column (3) of Table 3 are consistent with the benchmark regression results. The two indices as discussed to measure export volatility have passed the robustness test significantly. The results in columns (2) - (3) of Table 3 show that the export volatility measured by the absolute value of export growth rate and the variance of export growth rate for three consecutive years all verify the core conclusion that export market diversification can significantly reduce export volatility.

Third, we delete extreme values from the sample. In order to test whether the extreme value of each variable interferes with the empirical results, this paper conducts bilateral truncating on the sample at the 1% and 5% levels, respectively, and then performs another empirical test on the data excluding the extreme value. The regression results excluding extreme values are shown in columns (4) - (5) of Table 3. The regression results are consistent with the results in column (2) of Table 2, indicating that the benchmark regression results are not interfered with by the extreme values in each variable.

Table 3. Robustness check results.

	(1)	(2)	(3)	(4)	(5)
	Full sample			Winsor 1%	Winsor 5%
	Volatility	Absolute value of export growth rate	Volatility-3years	Volatility	Volatility
HHI	5.2082***				
	(0.2126)				
Disparity		2.1772***	2.8585***	5.0522***	4.1040***
		(0.1259)	(0.1315)	(0.2299)	(0.2830)
Control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Product fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	584684	611537	611537	509383	277978
Kleibergen-Paap rk Wald F statistic	1300.8760	1103.9480	1233.3840	1269.2660	966.8250

Note: This table mainly reports the regression results of the second stage of 2SLS regression. Robust standard errors in parentheses are clustered at the product level. The *, **, and *** superscripts indicate significance at the 10%, 5% and 1% levels, respectively. Winsor 1% and 5% indicate that the sample data are truncated bilaterally at the 1% and 5% levels, respectively.

4.3. Heterogeneity Analysis

We examine the impact of agricultural export market diversification on export volatility, but the impact of export market diversification for different types of products and countries at different levels of development may vary greatly. Therefore, in terms of product heterogeneity, we firstly divide agricultural products into five categories according to the chapter of agricultural products in the WTO "Agreement on Agriculture:" Products1 (live animal and animal products, Chapters 1 to 5), Products2 (plant products, Chapters 6 to 14), Products3 (animal or vegetable fats and oils and their cleavage products, prepared edible fats, and animal or vegetable waxes, Chapter 15), Products4 (food, beverages, wine and vinegar, tobacco and products, Chapters 6 to 24), and Products5 (other agricultural products). Second, according to the classification method of agricultural products by Regmi et al. (2005), agricultural products are divided into primary agricultural products and processed agricultural products. In terms of country heterogeneity, the sample countries and regions are classified according to the lists of developed countries or regions, emerging markets and developing countries or regions published on the official website of the International Monetary Fund. On this basis, the product heterogeneity and country heterogeneity of the agricultural export market diversification affecting export volatility are respectively explored.

Product heterogeneity. Table 4 presents the results of the product heterogeneity test on the impact of export market diversification on export volatility. Columns (1)-(5) are the regression results of 5 types of products classified according to the chapter of agricultural products in the WTO Agreement on Agriculture. From the regression results in the first row, it can be seen that the regression coefficient of export market diversification of plant products is the smallest, which is 3.9243. The regression coefficient of other agricultural products is the largest, which is 8.9138. Columns (6)-(7) of Table 4 are the regression results after dividing the sample into primary agricultural products and processed agricultural products, and the export market diversification all passed the test significantly. The export market diversification regression coefficient of processed agricultural products is larger than that of primary agricultural products. It reveals that compared with primary agricultural products, the improvement of the level of the export market diversification of processed agricultural products has a stronger effect on the stabilization of export volatility. The reason may be that, being non-necessities, processed agricultural products have higher import demand elasticity than primary

Table 4. Heterogeneity analysis results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Products1	Products2	Products3	Products4	Products5	Primary agricultural products	Processed agricultural products
	Volatility	Volatility	Volatility	Volatility	Volatility	Volatility	Volatility
Disparity	7.6556***	3.9243***	0.9242	5.7808***	8.9138***	5.6370***	5.8458***
	(0.6332)	(0.4117)	(1.9429)	(0.5937)	(0.8470)	(0.3042)	(0.5352)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	131736	211029	31476	176781	33658	391861	192822
Kleibergen-Paap rk Wald F statistic	201.2800	341.9970	71.2600	162.6080	150.7090	898.8180	212.4540

Note: This table mainly reports the regression results of the second stage of 2SLS regression. Robust standard errors in parentheses are clustered at the product level. The *, **, and *** superscripts indicate significance at the 10%, 5% and 1% levels, respectively. Products1 (live animal and animal products, chapters 1 to 5), Products2 (plant products, Chapters 6 to 14), Products3 (animal or vegetable fats and oils and their cleavage products, prepared edible fats, and animal or vegetable waxes, Chapter 15), Products4 (food, beverages, wine and vinegar, tobacco and products, Chapters 6 to 24), and Products5 (other agricultural products).

Table 5. Heterogeneity analysis results.

	(1)	(2)
	Developed countries or regions	Emerging markets and developing countries or regions
	Volatility	Volatility
Disparity	5.0012***	6.1893***
	(0.2554)	(0.4453)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Product fixed effects	Yes	Yes
Observations	341585	243098
Kleibergen-Paap rk Wald F statistic	1097.0570	557.1900

Note: This table mainly reports the regression results of the second stage of 2SLS regression. Robust standard errors in parentheses are clustered at the product level. The *, **, and *** superscripts indicate significance at the 10%, 5% and 1% levels, respectively. Volatility is the dependent variable.

agricultural products, which means the export volume of processed agricultural products of exporting countries is more sensitive to the price changes caused by external risk shocks. And, sample data analysis reveals that the average level of export diversification of processed agricultural products is lower than that of primary agricultural products. Therefore, compared with primary agricultural products, the exports of processed agricultural products are more sensitive to external risk shocks and have higher export concentration, so the improvement of the diversification level of the export market of processed agricultural products has a more obvious risk diversification effect, that is, the effect of stabilizing export volatility is stronger.

Country heterogeneity. According to the country classification on the official website of the International Monetary Fund, we divide the sample countries or regions into two categories: one is developed countries or regions, and the other is emerging markets and developing countries or regions. Table 5 shows the results of the country heterogeneity test. It can be seen from Table 5 that the export market diversification regression coefficient of the sample group of developed countries or regions is smaller than that of the sample group of emerging markets and developing countries or regions. This indicates that the increase in the level of export market diversification in developed countries or regions has a weaker effect on stabilizing the volatility of their agricultural exports than in emerging markets and developing countries or regions. The reason may be that the diversification level of export markets of emerging markets and developing countries or regions is relatively low (Lee and Zhang 2022), while that of developed countries or regions is already at a high level. Therefore, compared with emerging markets and developing countries or regions, the scope of new export markets in developed countries or regions is small, and the space for further diversifying export risks is narrow. So, when the level of export market diversification increases by the same amount, the effect of developed countries or regions on diversifying export risks is weaker than that of emerging markets and developing countries or regions.

5. Further Analysis

Based on the theoretical analysis of the impact mechanism in Section 2.2, this paper further examines the mechanism by which export market diversification affects export volatility. Referring to the mechanism research methods of Dell (2010), we use the following model to examine the mechanism.

$$Market\_share_{int} = \alpha_0 + \alpha_1 Disparity_{int} + \beta CV_{it} + \lambda_t + \mu_i + \gamma_n + \varepsilon_{int} \tag{16}$$

$$Duration_{int} = \alpha_0 + \alpha_1 Disparity_{int} + \beta CV_{it} + \lambda_t + \mu_i + \gamma_n + \varepsilon_{int} \tag{17}$$

where $Market\_share_{int}$ represents the international market share of country i's export product n in year t, presented by the ratio of the trade value of country i's export product n in year t to the total trade value of world export product n. The larger the value of $Market\_share_{int}$, the higher the share of the product n of country i in the international market. $Duration_{int}$ represents the duration of product n exported by country i in year t. The larger the value, the longer the export duration of product n from country i. The duration of a trade relationship is the time from the beginning to the end of the trade relationship between two countries for a certain product (Besedes and Prusa 2006). From the annual data of the continuous trade relationship measured by "exporting country – product - destination," we can obtain the length of years that the exporting country has continued in this trade relationship over the years, namely, the export duration used in this article.

The mechanism check results are shown in Table 6. The results in column (1) of Table 6 reveal that the *Disparity* coefficient is significantly negative. Since *Disparity* and the level of export market diversification change in opposite directions, the results in column (1) evidence that the improvement of the level of the agricultural export market diversification will significantly promote the increase of the international market share of agricultural products. Combining the theoretical mechanism analysis results in Section 2.2, i.e., the increase in the international market share of agricultural products will significantly reduce the volatility of agricultural exports, with the benchmark regression results in Table 2, we can conclude that the agricultural export market diversification reduces the volatility of agricultural exports by increasing the international market share. This conclusion proves that Hypothesis 2 holds. Through export diversification, the exporting countries integrate into the supply chain of the importing countries, gradually increasing the demand preference and trade dependence of the importing countries on their products, thus increasing the international market share of the export products. The increase in international market share has enhanced the ability to guarantee the safety of product supply and the resilience of product supply chains in exporting countries. It is conducive to reducing the probability of supply chain interruption and ensuring stable export growth when facing external risks, leading to a decline in export volatility.

According to the results in column (2) of Table 6, we can see that the *Disparity* coefficient is significantly negative. Combining the relationship between the *Disparity* value and the level of the export market diversification, we can determine that the improvement of the level of the agricultural export market diversification will significantly increases export duration. Combining the theoretical mechanism analysis results in Section 2.2, i.e., the extension of the export duration of agricultural products can significantly reduce export volatility, with the benchmark regression results in Table 2, we can conclude that the agricultural export market diversification can smooth the export volatility by extending the export duration. This conclusion proves that Hypothesis 3 holds. In the process of export market diversification, export firms constantly improve their production technology level through the "learning effect" and the "competition effect," thus promoting the improvement of firm

Table 6. Mechanism check results.

	(1)	(2)
	Market share	Duration
Disparity	−0.0788***	−3.5181***
	(0.0066)	(0.2406)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Product fixed effects	Yes	Yes
Observations	584684	584684
Kleibergen-Paap rk Wald F statistic	1236.0390	1236.0390

Note: This table mainly reports the regression results of the second stage of 2SLS regression. Robust standard errors in parentheses are clustered at the product level. The *, **, and *** superscripts indicate significance at the 10%, 5% and 1% levels, respectively.

productivity. Enterprises with high productivity can effectively resist the impact of external risks and reduce the probability of export interruption by depending on their competitive advantages (Ilmakunnas and Nurmi 2010). At the same time, export market diversification will also reduce the risk probability of export interruption through the "risk diversification effect." The diversification of the export market extends the duration of its exports by resisting and dispersing external risks, thereby enhancing the stability of trade relations and reducing the export volatility caused by the interruption of trade relations.

6. Conclusions and Policy Implications

Using the HS6-digit agricultural export data of various countries between 1996 and 2020, this paper studies the impact of agricultural export market diversification on the agricultural export volatility from the perspective of the world trade network. The study presented that a country's agricultural export market diversification is conducive to reducing the volatility of its agricultural exports. In terms of product heterogeneity, among the agricultural products in the various chapters of the WTO Agreement on Agriculture, the diversification of the export market of plant products has the weakest effect on the export volatility. The improvement of the level of export market diversification of processed agricultural products has a greater effect on the stabilization of the export volatility than that of primary agricultural products. In terms of country heterogeneity, the increase in the level of export market diversification in emerging markets and developing countries or regions has a greater buffering effect on the agricultural export volatility than in developed countries or regions. Further mechanism checks reveal that the agricultural export market diversification has stabilized the volatility of agricultural exports through two channels: increasing the international market share of agricultural products and extending the duration of agricultural exports. From the perspective of the trade network, the above conclusions provide strategy support for agricultural product suppliers to integrate into the global agricultural product supply chain, resist external risk shocks, ensure the steady growth of agricultural export volume, and assure the security of the global agricultural product supply chain. Last but not least, it provides experience for enhancing the resilience of international agricultural supply chain and solving the food security crisis.

Based on the research conclusions, this paper draws the following inspirations: First, each agricultural exporting country needs to improve its export strategies continuously. Agricultural exporting countries should actively built a global trade partnership network by creating a pattern of agricultural export trade with multiple export destinations and low export concentration. Agricultural product suppliers also need to participate profoundly in the global industrial division and cooperation, and maintain a diversified and stable international economic pattern and economic and trade relations. Second, there are natural differences in the effect of export market diversification for primary agricultural products and processed agricultural products to suppress the export volatility. Governments should encourage agricultural processing firms to enrich varieties, improve quality and create differentiated brands. The competent authorities should actively guide agricultural processing firms to build a complete process quality control, cleaner production, and traceability system. It can promote agricultural processing firms to produce safe, high-quality, green, and ecological products to meet the market access standards of more export destinations. Third, emerging markets and developing countries or regions should implement a more proactive opening strategy. These countries have to actively promote the signing of free trade agreements with more countries, build a global network of high-standard free trade areas, and form a broader scope, wider areas, and deeper opening-up pattern. Trading partners should continue to promote the vigorous development of bilateral, regional, and multilateral cooperative relations, strive to expand the convergence of interests with other countries, and jointly cultivate new momentum for global development.

Notes

1. Data source: FAO database. https://www.fao.org/faostat/en/#data.
2. See Table A1 in the Appendix for details.

Acknowledgments

The authors are very grateful to the editors and the anonymous reviewer for their constructive comments. The authors would also like to thank Dr. Chaokai Xu for assistance with data analysis methods.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

This research was supported by The National Social Science Foundation of China [grant number 20&ZD119].

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Appendix

Table A1. Sample countries and regions.

(1)	(2)	(3)	(4)
Afghanistan	Dominica	Lebanon	Saint Kitts and Nevis
Albania	Dominican	Lesotho	Saint Lucia
Algeria	Ecuador	Liberia	Saint Vincent and the Grenadines
Angola	Egypt	Libya	Samoa
Antigua and Barbuda	El Salvador	Lithuania	San Marino
Armenia	Equatorial Guinea	Luxembourg	Sao Tome and Principe
Aruba	Estonia	Macao, China	Saudi Arabia
Australia	Ethiopia	Macedonia	Senegal
Austria	Fiji	Madagascar	Seychelles
Azerbaijan	Finland	Malawi	Sierra Leone
Bahamas	France	Malaysia	Singapore
Bahrain	FS Micronesia	Maldives	Slovakia
Bangladesh	Gabon	Mali	Slovenia
Barbados	Gambia	Malta	Solomon Isds
Belarus	Georgia	Mauritania	South Africa
Belgium	Germany	Mauritius	Spain
Benin	Ghana	Mexico	Sri Lanka
Bhutan	Greece	Moldova	State of Palestine
Bolivia	Grenada	Mongolia	Sudan
Bosnia Herzegovina	Guatemala	Morocco	Suriname
Botswana	Guinea	Mozambique	Swaziland
Brazil	Guinea-Bissau	Myanmar	Sweden
Brunei Darussalam	Guyana	Namibia	Switzerland
Bulgaria	Haiti	Nepal	Syria
Burkina Faso	Honduras	Netherlands	Tajikistan
Burundi	Hong Kong, China	New Zealand	Tanzania
Cabo Verde	Hungary	Nicaragua	Thailand
Cambodia	Iceland	Niger	Timor-Leste
Cameroon	India	Nigeria	Togo
Canada	Indonesia	Norway	Tonga
Cayman Isds	Iran	Oman	Trinidad and Tobago
Central African Rep.	Iraq	Pakistan	Tunisia
Chad	Ireland	Palau	Turkey
Chile	Israel	Panama	Uganda
China	Italy	Papua New Guinea	Ukraine
Coate d'Ivoire	Jamaica	Paraguay	United Arab Emirates
Colombia	Japan	Peru	United Kingdom
Comoros	Jordan	Philippines	Uruguay
Congo	Kazakhstan	Poland	USA
Costa Rica	Kenya	Portugal	Vanuatu
Croatia	Kiribati	Qatar	Viet Nam
Cyprus	Kuwait	Rep. of Korea	Yemen
Czechia	Kyrgyzstan	Romania	Zambia
Dem. Rep. Congo	Laos	Russian Federation	Zimbabwe
Denmark	Latvia	Rwanda	