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The impact of mutual recognition of geographical indications on the quality upgrading of China's agricultural exports

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Improving the quality of agricultural exports and increasing value-added trade is crucial for shaping new competitive advantages of agricultural exports, building a strong trading nation and achieving high-quality agricultural development. This study constructed a multi-time point difference-in-differences model to empirically test the effect and mechanism of the mutual recognition of geographical indications (GIs) between China and the European Union (EU) on the quality upgrading of China's exported agricultural products from 2000 to 2016 based on theoretical analysis of the effect mechanism of GIs on agricultural product exports. The study determined that mutual GI recognition between China and the EU has effectively improved the quality of agricultural exports, with a greater effect on upgrading the quality of products from countries with high GIs endowment, quality frontier and large and medium-sized enterprises and labour-intensive products. The mechanism analysis revealed that mutual GI recognition between China and the EU can improve the quality of agricultural exports through specialisation agglomeration and cost-saving effects on the supply side and domestic demand upgrading and product recognition effects on the demand side. This study has important implications for further enriching quality improvement theory regarding agricultural products and presents a new approach for enhancing the quality improvement path of exported agricultural products that lack supply-side resources.

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Introduction

China is the world's largest producer and trader of agricultural products, yet its agricultural exports are 'big but not strong', with a trade deficit of $135.47 billion in 2021, of which soybeans, seeds and other important resource–based agricultural products have long been net imports. China's agricultural exports are still in the transition period from quantity– to quality–driven, and quality upgrading is not progressing, caught in the dilemma of agricultural quality upgrading (Liu and Dong, 2021), resulting in the export market for some agricultural products such as tea shifting from developed to developing countries.

Geographical Indications (GIs) are a special type of intellectual property right that specify the origin and quality characteristics of a product. Regional public brands of agricultural products formed on the basis of GI certification have been striving to develop new competitive advantages with technology, brand and quality as the core and have an important influence on promoting the quality and price of exported GI agricultural products, increasing farmers' income, advancing rural revitalisation and establishing a strong trading nation (Lu, 2021). In recent years, China has continuously increased the protection of its GI products, adjusted and improved laws and regulations, strengthened dialogue and cooperation with the international community and sought to establish a mutually beneficial and 'win–win' trade pattern in the GI industry. In 2007, China and the European Union (EU) launched the China–EU '10 + 10' pilot project of mutual GI recognition. The China General Administration of Quality Supervision, Inspection and Quarantine and the EU delegation officially exchanged documents related to 10 GI–protected products in each country, all of which were mutually cross–certified in November 2012. As a pilot product for mutual GI recognition between China and the EU, Jinxiang garlic has an average annual production of about 1 million tonnes, its export volume accounts for >70% of the country's total export volume and this single agricultural product ranks first in the country in terms of foreign exchange.[1]

Theoretically, the new competitive advantage of GI products following mutual recognition can come from both supply and demand sides. For example, on the supply side, mutual GI recognition between China and the EU transforms agricultural products from undifferentiated homogeneous goods into differentiated commodities. On the demand side, more locally well–known products from China and the EU enter one another's markets under legal protection, expanding the market scope of such products. Does mutual GI recognition help to improve the quality of China's agricultural exports? If so, does this promotion come from the supply side or the demand side? What is the mechanism? Are there heterogeneous effects on different export markets, products and firms?

Two categories of literature are closely related to this study. The first body of literature concerns the quality of exported agricultural products. Research on product quality was first introduced by Linder (1961), who asserted that the level of per capita income was the primary variable determining trade and countries with higher income levels also had higher product quality requirements. Since this introduction, research on product quality has been conducted from theoretical and empirical perspectives. In terms of theoretical research, Flam and Helpman (1987) used a north–south difference model to introduce quality differences into vertical industry trade theory. However, Melitz (2003) was the first to question the assumption of homogeneity among producers, establishing a novel trade theory from which scholars really began to consider product quality variability. In terms of empirical research, the most common methods to measure agricultural product quality include the unit value method (Schott, 2004), the post hoc backcasting method (Khandelwal et al., 2013; Shi and Shao, 2014) and the nested logit model (Dong and Huang, 2016). Regarding the factors which influence the quality of exported agricultural products, some studies have found that trade measures such as sanitary and phytosanitary (SPS) measures, positive list systems and maximum residue limits implemented by importing countries inhibit the quality upgrade of China's exported agricultural products (Dong and Liu, 2019; Chen and Xu, 2017; Jiang and Yao, 2019). Other studies have demonstrated that economic factors such as foreign direct investment, optimising the institutional environment and reducing policy uncertainty also contribute to increasing the value and quality of export products significantly (Ciani and Imbruno, 2017; Hu and Zhao, 2018; Sun and Anwar, 2019). Cage and Rouzet (2015) determined that the free–riding behaviour of a considerable number of low–quality firms protected by regional quality reputations leads to dilemmas for export quality upgrading; however, Dong and Gao (2020) argued regional quality reputations to promote the quality upgrading of exported agricultural products through competitive market and technology spillover effects.

The second body of literature is the study of the effect of GIs on export trade. With the inclusion of GI certification in intellectual property rights negotiations and its inclusion in the Agreement on Trade–related Aspects of Intellectual Property, the impact of GI on export trade has gradually attracted wide attention from domestic and international scholars. Crozet et al. (2012) found that Champagne producers characterised by high–quality ratings tended to export to larger markets and that the more they export, the higher the export price is. Similarly, Raimondi et al. (2020) and Filippis et al. (2022) demonstrated that GI has a facilitating effect on agricultural exports to both internal and external EU countries, but the trade facilitating effect of GI becomes weaker when the importing country has GI products. It has also been argued that GI certification can lead to higher production costs for firms, which can crowd out productive investments and reduce export competitiveness in international markets (Moschini et al., 2008; Bienabe and Marie–Vivien, 2017). Regarding the impact of geographical indication on export quality, scholars have found that GI certification can force firms to innovate to improve productivity, helping them to develop comparative trade advantages and improve export quality (Merel and Sexton, 2012; Agostino and Trivieri, 2014).

Some previous research has examined the impact of GI on export trade, but there are notable shortcomings. First, there is little literature on the trade effects of bilateral geographical indications. Unlike unilateral GI certification in exporting countries, bilateral mutual GI recognition emphasises superior treatment and contractual guarantees for products from GI mutual recognition partner countries (Filippis et al., 2022). In the context of GI mutual recognition, only Curzi and Huysmans (2022) have examined the trade effects of the inclusion of GI legal protection in 11 free trade agreements (FTAs) in EU countries, finding the inclusion of GI protection in FTAs to promote the binary margin of cheese exports from EU countries. Minimal literature has systematically investigated the relationship between mutual GI recognition and firms' export quality from the perspective of this study, and the existing literature primarily focuses on European firms, while there is a paucity of research regarding firms from developing countries, particularly Chinese firms. Second, there is a lack of studies on the trade effects of GIs from the perspective of demand side of the destination country. Existing studies predominantly focus on the supply–side endowment of GIs in exporting countries, while insufficient attention has been given to demand–side factors. A firm's comparative advantage in exports can come from the supply side, for instance, through the

production of high–quality products and the demand side, through more stable trade relations and larger market demand. Therefore, it is essential to move from single–path analyses of the supply side to dual–path analyses of supply and demand sides.

Thus, this paper constructs a multi–time point difference–in–differences (DID) model based on Chinese customs export data from 2000 to 2016 to empirically test the effect of mutual GI recognition between China and the EU on the quality upgrading of China's exported agricultural products and its mechanism. The possible contributions of this study are as follows. In terms of research perspective, this study expands the research perspective from unilateral GI certification by exporting countries to bilateral mutual GI recognition, taking agricultural products with mutual GI recognition in China and EU as the starting point, focusing on the effect of mutual GI recognition on the quality upgrading of exported agricultural products, exploring whether mutual GI recognition can establish new advantages for China's agricultural exports and producing theoretical and empirical contributions. In terms of research content, this study decomposes the impact of mutual GI recognition on the quality upgrading of exported agricultural products from supply and demand sides and examines the mechanism of the supply– and demand–side mutual GI recognition between China and the EU in improving the quality of exported agricultural products. The results reveal path–dependent features of quality improvement on exported agricultural products on both supply and demand sides. These findings provide important insights for enriching the theory of quality upgrading of exported agricultural products and presents a new approach for the path of quality upgrading of exported agricultural products without supply side resources. In terms of research significance, this study examines the impact of mutual GI recognition on the quality upgrading of exported agricultural products, enriching the research results of quality information asymmetry and collective reputation in the field of international trade and expanding the theoretical framework of comparative advantage. In addition, this study determines that mutual GI recognition can promote the quality upgrading of agricultural export products, validating the comparative advantage of GI endowment reputation and expanding the research on the sources of comparative advantage.

Theoretical analysis and research hypothesis

Theoretical model. Referencing the theoretical analytical frameworks of Melitz (2003) and Antoniades (2015), this study incorporates mutual GI recognition into a heterogeneous product model and explores the impact of mutual GI recognition on the quality upgrading of agricultural products on supply and demand sides in China and the EU.

Demand side. Consider a static partial equilibrium model with a representative consumer utility function for the importing country i, as follows:

$$U = q_0^i + \alpha \int_{k\in\Omega} q_k^i dk + \beta \int_{k\in\Omega} \lambda_k q_k^i dk - \frac{1}{2}\gamma \int_{k\in\Omega} (q_k^i)^2 dk - \frac{1}{2}\eta\left(\int_{k\in\Omega} (q_k^i)^2 dk\right)^2 \quad (1)$$

where q_0^i and q_k^i are the consumption of homogeneous and differentiated products by consumers in country i, respectively, and λ_k is the quality of product k, α indicates the magnitude of the utility gained from consuming the differentiated product and β reflects the degree of preference for product quality by consumers in country i. The higher the coefficient of β is, the higher the consumer preference for product quality in country i. γ indicates the degree of differentiation of the differentiated product, the lower the coefficient of γ is, the higher the substitution of product k. η indicates the elasticity of substitution between homogeneous and differentiated products, the lower the coefficient of η is, the higher the consumer demand for the differentiated product. According to the principle of consumer utility maximization, the demand function for differentiated product k of representative consumers in country i can be obtained as follows.

$$q_k^i = \frac{I}{\gamma}\left(\alpha + \beta\lambda_k - \eta Q_k^i - p_k^i\right) \quad (2)$$

Extrapolated to a market of size L, the total market demand function is as follows.

$$q_k^i = \frac{L}{\gamma}\left(\alpha + \beta\lambda_k - \eta Q_k^i - p_k^i\right) \quad (3)$$

Supply side. Assuming a perfectly competitive market for homogeneous products and an imperfectly competitive market for differentiated products, there are sunk costs f_E and marginal costs c for firms to enter the market. Suppose that marginal cost c is a random variable that follows the distribution $G(c)$, $[0, c_M]$. A lower coefficient of c indicates higher firm productivity. Mutual GI recognition requires producers to comply with relevant production standards and codes of practice to meet importers' product quality standards. Subsequent improvement in product quality comes from investment in upgraded production technology motivated by GI certification requirements. Therefore, product quality and improvement in production efficiency are captured in the following equation:

$$\Delta\lambda_k = \delta_\lambda \theta_k (I_k)^{\frac{1}{2}}; \Delta c_k = \delta_\varphi \theta_k (I_k)^{\frac{1}{2}} \quad (4)$$

Where I_k, $\Delta\lambda_k$, Δc_k and δ_λ denote the firm's technological inputs, the magnitude of the improvement in product quality, the magnitude of the improvement in productivity, and the impact of technological inputs on product quality, respectively. δ_φ is the coefficient of the impact of technological inputs on marginal costs of production, and the differences in the improvement in product quality and productivity by different types of production technological inputs are mainly reflected by the coefficient of δ_φ. θ_k indicates the heterogeneity of a firm's technological input capability; the larger the coefficient of θ_k is, the more the firm's quality performance improves.

The total cost of production for a firm after including its technological inputs is as follows:

$$TC_k = q_k^c(c_k + \mu\lambda_k) + \left(\frac{\Delta\lambda_k}{\theta_k\delta_\lambda}\right)^2 \quad (5)$$

Where $q_k^i(c_k + \mu\lambda_k)$ is the variable cost of producing q_k^i unit of product. c_k and λ_k are the productivity and product quality of the firm after GI mutual recognition. $c_k = c_{k0} - \Delta c_k$ is the productivity of the firm before GI mutual recognition. $\lambda_k = \lambda_{k0} + \Delta\lambda_k$, λ_{k0} is the product quality of the firm before GI mutual recognition. By combining the demand function and the cost function, the profit function of the firm producing product k can be obtained as follows.

$$\pi(i,\lambda) = \frac{L}{4\gamma}\left[\alpha - \eta Q_k^i - c_{k0} + \Delta c_k + (\beta - \mu)(\lambda_{k0} + \Delta\lambda_k)\right]^2 - \left(\frac{\Delta\lambda_k}{\delta_\lambda}\theta_k\right)^2 \quad (6)$$

From Eq. (4), $\Delta c_k = \frac{\delta_\varphi}{\delta_\lambda}\Delta\lambda_k$, which is substituted in Eq. (6) for the partial derivative of $\Delta\lambda_k$, the optimal improvement of the product quality can be obtained as follows.

$$\Delta\lambda_k = \phi[\alpha - \eta Q_k^i + (\beta - \mu)\lambda_0 - c_k] \quad (7)$$

Where $\phi = L\left(\beta - \mu + \frac{\delta_\varphi}{\delta_\lambda}\right)/[4\gamma(\delta_\lambda^{-2}\theta_k^{-2} - L(\beta - \mu)^2]$ is the product quality improvement factor of the firm after GI mutual

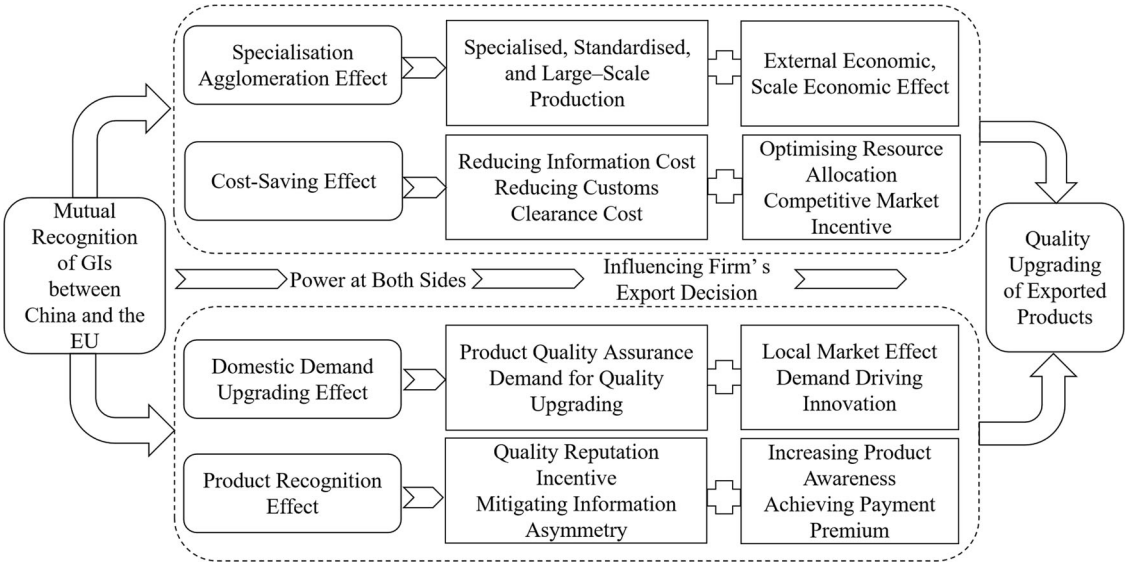

Fig. 1 Mechanism of the mutual recognition of geographical indications between China and the EU in improving the quality of exported agricultural products. Depicts the mechanism of the mutual recognition of geographical indications between China and the EU in improving the quality of exported agricultural products.

recognition. Let $c_D \equiv \alpha - \eta Q_k^i + (\beta - \mu)\lambda_0$ be the critical point of the firm's survival cost, if the firm's production cost c is higher than c_D, the firm will exit the market. Therefore, the optimal product quality upgrading degree of product k can be simplified to as follows.

$$\Delta\lambda_k = \phi(c_D - c_k) \tag{8}$$

Closed market equilibrium. The closed market equilibrium condition is that the expected profit of a firm entering the market is equal to the cost of participation (f_E), which implies the following.

$$f_E = \int_0^D \pi(c,\lambda)dG(c) = \frac{L}{4\gamma}(1+\beta\phi)\int_0^D (c_D - c_k)^2 dG(c) \tag{9}$$

Assume that c obeys the Pareto distribution, $G(c) = \left(\frac{c}{c_M}\right)^m$, solving for the threshold to enter the domestic market as follows:

$$c_D = \left[\frac{2\gamma C_M^m f_E(m+1)(m+2)}{L(1+\beta\phi)}\right]^{\frac{1}{m+2}} \tag{10}$$

Combining Eqs. (8) and (10), it can be concluded that a more extensive product quality improvement coefficient of ϕ denotes greater product quality improvement, and a higher productivity level c_k denotes a stronger incentive to improve product quality. Investment in technology is a basic way for firms to achieve product quality upgrading in exports. Mutual GI recognition will raise firms' product quality upgrading factor, promote product quality innovation and further advance the quality of export products.

Open market equilibrium. Trade costs are inherently associated with moving products across borders, which are set using an iceberg cost approach (i.e. one unit of product entering a foreign market requires the production of τ ($\tau > 1$) units of product). Under open conditions, the firm is assumed to have a domestic entry threshold c_D'. When $c_D' < c$, the firm will exit the market, when $\frac{c_D'}{\tau} < c < c_D'$, the firm only sells domestically and when $\frac{c_D'}{\tau} > c$, the firm sells both domestically and internationally. Again assuming that c obeys the Pareto distribution, solving for the firm's entry threshold under open conditions yields the following.

$$c_D' = \left\{\frac{2\gamma C_M^m \tau^m f_E(m+1)(m+2)}{\tau^m L[1+\beta\phi] + L'[1+\beta\phi']}\right\}^{\frac{1}{m+2}} \tag{11}$$

Under open conditions, the firm faces both domestic and foreign market incentives, so the optimal product quality improvement for the firm is as follows:

$$\Delta\lambda_{open}^* = \frac{L\beta(c_D' - c) + L'\beta(c_D' - \tau c)}{4\theta\gamma - (L - L')\beta^2} \tag{12}$$

The partial derivative of Eq. (12) is as follows:

$$\frac{\partial\Delta\lambda_{open}^*}{\partial\tau} < 0\,;\ \frac{\partial\Delta\lambda_{open}^{*\,2}}{\partial\tau\partial p} < 0 \tag{13}$$

Equation (13) indicates that trade cost is a significant factor affecting the quality of export products, and the quality of firm export products is expected to improve when trade cost decreases. Trade cost significantly affects the efficiency of mutual GI recognition in promoting export product quality. In this scenario, lower trade cost from mutual GI recognition has a greater promotional effect on export product quality; therefore, hypothesis 1 is proposed:

H1: Mutual GI recognition between China and the EU improves export product quality.

Mechanisms. From the above derivation, it is clear that firm productivity, trade costs and consumer preferences are significant factors of influence which advance the effect of mutual GI recognition on quality upgrading, and the specific mechanisms of these factors in influencing quality upgrading are further explored below (see Fig. 1).

Supply–side mechanisms: specialisation agglomeration and cost-saving effects

Specialisation agglomeration effect: Mutual GI recognition between China and the EU established unified group quality standards for products covering cultivation, processing and marketing. This unites farmers and firms with relatively scattered production scales under leading firms for standardised production, highlighting the unique quality of GI products, rapidly

enhancing regional competitive advantages and forming a specialised industrial agglomeration model (Moschini et al., 2008). Industrial agglomeration allows firms to obtain benefits from external economies of scale; accelerates shared information resources, technical cooperation and knowledge spillover; and improves product quality through exchange and cooperation (Marshall, 1890). In addition, technology demonstration and knowledge spillover effects from leading firms will further drive regional firms to improve product quality (Raimondi et al., 2020). Under the influence of the external economy and driven by leading firms, firms will also allocate more resources to mutual GI recognition products, narrowing the range of export products, increasing the concentration of export products and improving product quality (Mayer et al., 2014). Thus, the following hypothesis is proposed:

H2: Mutual GI recognition between China and the EU improves the quality of exported agricultural products through the specialisation agglomeration effect.

Cost-saving effect: Mutual GI recognition increases marginal benefits and equilibrium product quality by reducing trade costs. The China–EU GI Agreement stipulates the GI protection rules and GI mutual recognition list, which clearly states the origin information, production specifications and quality standards of mutually recognised products, reducing the information acquisition and information export costs for firms (Menapace and Moschini, 2012). GI holders are not required to apply separately to the EU for products under mutual GI recognition from China and the EU, which saves firms considerable information expenditure in terms of the application process and supporting documents, making it more convenient and less costly for firms to obtain GI protection and reducing export clearance costs (Wang and Lin, 2012). The reduction of information and trade costs results in enterprises' migration, entry and exit, which cultivates market competition. Fierce market competition can promote efficient resource allocation among established enterprises, stimulate established enterprises to invest in innovation, improve productivity and increase the marginal revenue and corresponding optimal marginal expenditure of enterprise quality improvement. And then improve the quality of export products (Yang and Li, 2021). Thus, the following hypothesis is proposed:

H3: Mutual GI recognition between China and the EU improves the quality of exported agricultural products through the cost-saving effect.

Demand–side mechanisms: domestic demand upgrading and product recognition effects

Domestic demand upgrading effect: New trade theory emphasises that increased exports are driven by the economy of scale created by increased domestic demand within a country, and the expansion of exports is spurred by a strengthening local market effect (Krugman, 1980). When the local market effect is shaped by a country's higher quality demands, it generated increased capital and motivates firms to improve product quality (Latzer and Mayneris, 2021). Mutual GI recognition in China and the EU ensures that products are cultivated in the most suitable areas, produced following specified standards and are perceived by consumers as higher quality, differentiated speciality products (Filippis et al., 2022). As per capita income continues to rise, particularly with the development of a 400 million strong middle class in China, demand for quality agricultural products has risen. Products certified by developed countries in the EU and the US are perceived by consumers as high quality. Domestic middle– and high–income consumers also prefer high–quality, differentiated products with mutual GI recognition, which unlocks the potential of local markets and stimulates export dynamics (Dong and Shen, 2021). Produced by the upgraded demand structure, this local market effect motivates firms to invest more in technological innovation, causing more productive firms to choose to export high–quality agricultural products while satisfying local demand (Ma and Cao, 2022). The following hypothesis is proposed:

H4: Mutual GI recognition between China and the EU improves the quality of exported agricultural products through the domestic demand upgrading effect.

Product recognition effect: Mutual GI recognition between China and the EU provides effective legal protections against counterfeiting and falsification in addition to establishing a good quality reputation for certified products (Calboli, 2015). The quality reputation of mutual GI recognition provides EU consumers with sufficient information regarding product quality prior to purchase, partially decoding the empirical product trust attribute of agri–food commodities, enhancing EU consumers' perception of product quality and strengthening the influence of product quality information in consumers' purchase decisions, resulting in continuous amplification of the perceived value of mutual GI recognition products with quality advantages, which increases consumers' willingness to purchase and pay substantial premiums (Radhika et al., 2021). The expansion of market demand in destination countries is expected to encourage enterprises to increase the export scale to EU countries and raise the probability of export. Enterprises will adjust production activities based on emerging demand and strengthen the differentiation advantages of characteristic agricultural products. In addition, the requirements of mutual GI recognition regarding product standards, inspection, quarantine, enterprise registration and certification (Aghion et al., 2018) and quality access thresholds related to the EU's SPS and technical barriers to trade (TBT) measures encourage enterprises to allocate more resources to quality improvement, advance quality supervision levels in production processes and enhance export products' quality (Arumugam 2019). Thus, the following hypothesis is proposed:

H5: Mutual GI recognition between China and the EU improves exported agricultural product quality through the product recognition effect.

Materials and methods

Model setting. This study examines whether mutual GI recognition promotes the quality upgrade of exported agricultural products, taking mutual GI recognition as a quasi–experimental pilot variable to investigate its impact. The most commonly used method for investigating the impact of policy shocks is the DID model. This study employs this method to analyse the impact of mutual GI recognition on the quality of exported agricultural products. Due to the different timing of mutual GI recognition for specific products from China and the EU,[2] we adopt a method that recognises the gradual approval of mutual GI recognition. Subsequently, the study adopts an expansive multi–time point DID model, referencing the general analysis framework of the DID model by Hansen. The multi–time point DID model (Beck et al., 2010) was developed to evaluate the effect of mutual GI recognition between China and the EU on China's agricultural exports. Consequently, all agricultural products of mutual GI recognition between China and the EU at different time points are included in the same model, with products prior to mutual recognition employed as the control group becoming the treatment group following the implementation of mutual GI. In addition, individual fixed and time fixed effects are controlled to establish a multi–time point DID bidirectional fixed effect model.

The specific model is constructed as follows:

$$Y_{fkjt} = \alpha + \beta Treat_{fkj} \times Post_{fkjt} + \gamma \sum Control_{kjt} + \lambda_{ft} + \lambda_{kt} + \lambda_{jt} + \varepsilon_{fkjt} \quad (14)$$

λ_{ft}, λ_{kt} and λ_{jt} respectively represent firm–year, product–year and destination country–year fixed effects, controlling for unobservant variables that change over time in firm, product and destination country; ε_{fkjt} is the error term, clustered at the HS6 digit code product level. β is the core estimation parameter, which represents the net effect of mutual recognition of geographical indications on agricultural exports between China and the EU.

Measures

Explanatory variable. The explanatory variable is the quality upgrading of China's agricultural products ($delt\_quality_{fkjt}$), with the difference in quality between current and previous periods representing the quality improvement. For the measure of product quality, referencing Khandelwal et al. (2013) and Shi (2014), the regression of Eq. (15) is calculated as follows.

$$lnq_{fjkt} + \sigma_k lnp_{fjkt} = \delta_k + \delta_{jt} + \varepsilon_{fjkt} \quad (15)$$

where q_{fjkt} and p_{fjkt} denote the quantity and price of the firm's exported product, respectively, σ_k denotes the elasticity of substitution of product k, and and δ_k and δ_{jt} denote the product–fixed effect and the time–fixed effect of the importing country, respectively, ε_{fjkt} denotes the residual component. Using sample data on price and quantity, an OLS regression of the above equation yields the estimated product quality, expressed as follows.

$$quality_{fjkt} = \frac{\hat{\varepsilon}_{fjkt}}{\sigma_k - 1} \quad (16)$$

The result of Eq. (16) is normalized to give the final expression of product quality as follows.

$$quality'_{fjkt} = \frac{quality_{fjkt} - minquality_{fjkt}}{maxquality_{fjkt} - minquality_{fjkt}} \quad (17)$$

where $maxquality_{kt}$ and $minquality_{kt}$ are the maximum and minimum values of the quality of product k exported to all destination countries in year t, $quality'_{fjkt}$ is the quality of product k exported by firm f to country j in year t.

Policy variable. $Treat_{fkj}$ is the grouping variable of whether the product is mutual recognition of GI product between China and the EU; if it is, $Treat_{fkj}$ equals to 1; otherwise $Treat_{fkj}$ equals to 0. $Post_{fkjt}$ is a dummy variable for the treatment period, which indicates whether product k exported to country j by firm f in year t is the product of mutual recognition of GI between China and the EU; if it is, $Post_{fkjt}$ equals to 1; otherwise, $Post_{fkjt}$ equals to 0. This study explores the effect of the mutual recognition of geographical indications between China and the EU on agricultural exports by examining the effect of their cross terms on the explained variables.

Control variables. This paper also controls for other variables that affect the quality improvement of exported agricultural products, where SPS_{kjt} represents the SPS measures of the importing country and is measured by the number of notifications from the importing country at the level of HS2 digit code in period $t-1$; $open_{jt}$ represents the importing country's opening level, represented by the proportion of the importing country's total imports and exports in its GDP, which is used to measure the degree of correlation of the importing country's foreign economy; $pgdp_{jt}$ represents the per capita income level of the importing country, which is used to measure the importing country's consumption level; $exchange_{jt}$ represents the exchange rate of RMB, which is converted using the US dollar as the intermediary measurement standard to control for the impact of trade costs; $endowment\_diff_{kjt}$ is the difference in importing and exporting countries' GI endowment, which is measured by the difference in the number of GI possessed by the exporting and importing countries in HS codes.[3]

Sample and data sources. Based on the completeness and availability of data, this study selects the annual data of Chinese firm–product–destination exporting country in the EU as the research sample. The sample period includes 28 member states spanning from 2000 to 2016.[4] The agricultural products studied primarily cover HS02 (Meat), HS03 (Aquatic products), HS04 (Dairy products), HS07 (Vegetables), HS08 (Fruits), HS09 (Coffee, tea and spices), HS19 (Grain, grain powder) and HS22 (Beverages, wine and vinegar), which are mutually recognized GI products between China and the EU. Considering that Chinese customs data before and after 2002 uses inconsistent HS codes, as Chinese customs data before 2002 use encoding on the basis of the HS96 and after 2002 is based on HS02, according to the website provided by the HS6 code conversion table, the data need to be adjusted to make the HS codes consistent and transform the customs data to the HS6 code. After integrating the above data, 240,814 samples of Chinese agricultural products exported to the EU in from 2000 to 2016 are finally obtained.

The data are obtained in the following ways. The export data of HS6 digit code at the level of firm–product–destination country are from the China Customs database. SPS measure data are obtained from the World Trade Organization (WTO) SPS Measure Notification System (https://i-tip.wto.org/). Importing countries' degree of opening, exchange rate and per capita GDP data are from the World Bank's World Development Indicators database (https://wits.worldbank.org/). Exporting country (China) GI data are from the China State Intellectual Property Office (https://www.cnipa.gov.cn/), the China State Administration of Market Supervision and Management (https://www.samr.gov.cn/), the China Ministry of Agriculture and Rural Affairs (http://www.moa.gov.cn/) and the Geographical Indication Network (http://www.cpgi.org.cn/). Importing countries' (EU) GI data are obtained from the eAmbrosia database (https://ec.europa.eu/). The descriptive statistics of variables are presented in Table 1.

Empirical results and analysis

Typical facts and priori judgement. To reflect the changes in exported agricultural product quality between the treatment and control groups during the sample period, this study employs curves to depict the trends in the average quality indices of exported agricultural products between treatment and control groups (see Fig. 2). In 2010, Longkou Vermicelli was the first product to be approved for mutual GI recognition between China and the EU, followed by Guanxi Honey Pomelo, Lixian Hemp Yam and West Lake Dragon Well Tea. Figure 2 reveals fluctuations in the quality index of exported agricultural products between the treatment and control groups prior to 2010, and the quality index of China's exported agricultural products generally presents an upwards trend after 2010. Furthermore, the growth trend of export quality was significantly stronger for the treatment group than that of the control group. In particular, the increase in the treatment group's export quality index was higher after 2012, indicating that the quality of exported agricultural products was affected by factors such as mutual GI recognition

Table 1 Variable definitions and descriptive statistics.

Variable type	Variable name	Variable symbol	Observation	Mean	Standard deviation	Minimum	Maximum
Explained Variable	Quality upgrading of Agricultural product	*delt_quality*	240,814	0.0095	0.2231	−0.1783	0.1987
Policy Variable	Dummy variable for mutual recognition of GIs between China and the EU	*Treat*Post*	240,814	0.0127	0.3121	0.0000	1.0000
Control Variable	SPS measure	*SPS*	240,814	1.5891	1.1191	0.0034	3.8839
	per GDP	*pgdp*	240,814	0.7319	0.4087	0.2729	1.8209
	Degree of openness	*open*	240,814	8.1628	1.2238	6.7992	11.1653
	Exchange rate	*exchange*	240,814	22.9925	10.1291	0.0000	46.0000
	Difference in GI endowments between importing and exporting country	*endowment_diff*	240,814	17.4358	29.0663	0.0000	34.0000

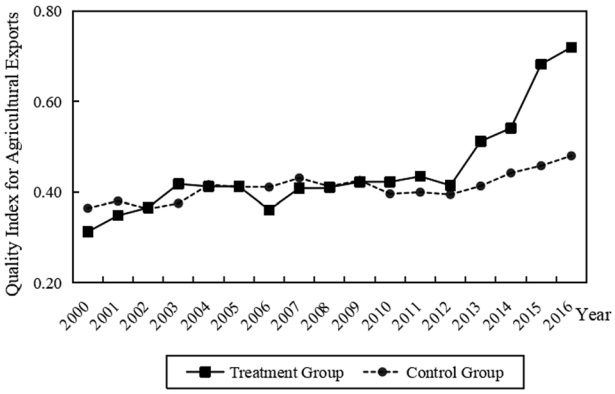

Fig. 2 Trends in the quality of agricultural exports. Depicts the trends in the average quality indices of exported agricultural products between treatment and control groups from 2000 to 2016.

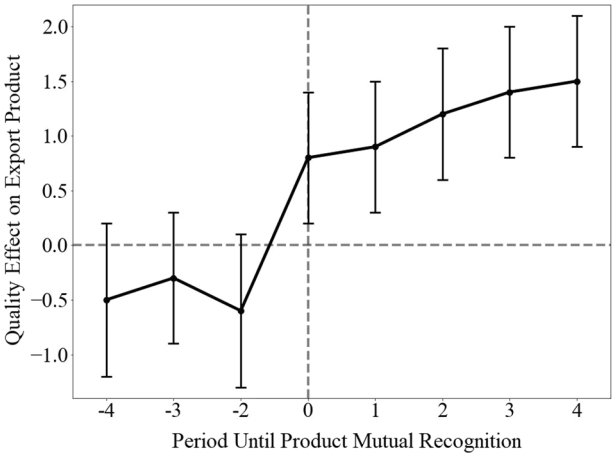

Fig. 3 Dynamic effects of the quality of agricultural exports. Reveals that the promotional effect of the quality of exported agricultural products fluctuates prior to mutual GI recognition pilot project, indicating a dynamic growth trend following implementation of mutual GI recognition.

and changes in the international trade environment. As an ex–ante test, Fig. 2 demonstrates that the difference in export quality between the treatment and control groups correlates with mutual GI recognition between China and the EU, establishing an a priori judgement for our empirical study using the multi–time point DID model.

Parallel trend test. Appropriate use of the multi–time point DID model must satisfy the assumption of parallel trends, and prior to the implementation of mutual GI recognition between China and the EU, the trend of changes in the quality of China's exports of recognised products (treatment group) and non–recognised products (control group) must be approximately the same. Under this assumption, changes in the quality of exported agricultural products after the effective date of mutual GI recognition can be considered to represent the effect of the policy intervention. Therefore, a parallel trend test for the quality of exported agricultural products is first conducted by setting each year in the sample period as a dummy variable and multiplying it by the treatment group dummy variables to perform a regression test. If the regression results are not significant in any of the years prior to mutual GI recognition, then the model is considered to be consistent with the parallel trend assumption. The results are presented in Fig. 3, revealing that the promotional effect of the quality of exported agricultural products fluctuates prior to mutual GI recognition pilot project, indicating a dynamic growth trend following implementation of mutual GI recognition. This confirms the required parallel trend for applying the multi–time point DID model.

Analysis of regression results of multi–time point DID model. To overcome any systemic bias due to the heterogeneity between mutually recognised and non–mutually recognised products, this study applies a propensity score matching (PSM) multi–time point DID (PSM–DID) model for empirical testing. Referencing Baier and Bergstrand (2007), this study considers the factors influencing the China–EU mutual GI recognition agreement, such as the importing country's SPS measures (SPS_{kjt}), the importing country's degree of openness ($open_{jt}$), the importing country's per capita income level ($pgdp_{jt}$), and the difference in the GI endowment of the importing and exporting countries ($endowment\_diff_{kjt}$), as matched covariates, and uses the one–to–one non–replication nearest neighbour matching method to find the best control group for the treatment group year by year.

Table 2 presents the results of our baseline regression analysis. Column (1) includes only the core explanatory variable of the interaction term of time and policy dummies, column (2) introduces control variables and column (3) adds control variables and controls for firm–year, product–year and country–year fixed effects. Columns (1) and (3) exhibit significant positive coefficients, indicating that mutual GI recognition between China and the EU considerably improves the overall quality of exported agricultural products and advances the quality improvement of China's exported agricultural products, validating H1. From the supply side, the high level of protection provided by mutual GI recognition eliminates firms' time and expenses for application procedures and supporting documents and reduces the cost of information collection, and the uniform production standards established by the implementation of mutual

Table 2 Benchmark regression result.

	delt_quality (1)	*delt_quality* (2)	*delt_quality* (3)
Treat × *Post*	0.6915***	0.0274	0.9407***
	(3.40)	(0.13)	(4.39)
SPS		0.0830***	−0.2143***
		(3.65)	(−8.97)
open		0.2415***	0.3217***
		(3.40)	(4.27)
pgdp		0.6675***	0.8031***
		(27.49)	(31.02)
exchange		−0.0006***	−0.0010***
		(−5.83)	(−8.82)
endowment_diff		0.0669***	0.0644***
		(24.91)	(21.44)
cons	2.1361***	0.1643	1.0800***
	(93.12)	(0.65)	(4.04)
Firm—Year Fixed Effect	NO	NO	YES
Product—Year Fixed Effect	NO	NO	YES
Country—Year Fixed Effect	NO	NO	YES
R^2	0.0001	0.0134	0.0180
N	133785	133785	133785

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

GI recognition makes firms more comfortable navigating SPS and TBT measures and more capable of overcoming export barriers and achieving export quality improvement. From the demand side, mutual GI recognition gives products a 'halo', which raises the demand for mutually recognised products from domestic and international consumers who are willing to pay higher prices, with an obvious impact on the quality of export products.

Control variables align with expectations. The coefficients of the three control variables of GDP per capita in importing countries, openness and differences in GI endowments in importing and exporting countries are positive, suggesting that high economic levels and openness degree; moreover, the presence of more GI products in importing countries contribute to the quality upgrading of agricultural products from China. The coefficient of exchange rate is negative, indicating that an increase in the RMB exchange rate hinders the quality upgrading of exported agricultural products. The coefficient of SPS on agricultural quality upgrading is uncertain, possibly because the impact of SPS measures on quality upgrading depends on the magnitude of compliance and market transfer costs (Liu and Dong, 2021).

Robustness tests. This study conducts four robustness tests to ensure the accuracy of the baseline regression results, including replacing the dependent variable, sample tail reduction and truncation treatment, modifying the PSM matching method and a placebo test.

Replacing the dependent variable. The explanatory variable of export quality (*delt_quality*) is replaced with a dummy variable (*dum_quality*), which takes the value of 1 if the export quality of the current period is higher than that of the previous period; it is 0 otherwise. The results in Table 3 are consistent with those of the baseline regression, indicating that the baseline regression results are robust.

Sample tail reduction and truncation treatment. To avoid the influence of outliers on the estimation results in measuring the quality of exported agricultural products, referencing Crinò and Ogliari (2015), this study applies bilateral tail reduction and truncation treatment to the samples, thus removing outliers from the quality data for exported agricultural products at 1% and 5% quartiles and re–estimates Eq. (1) using the treated samples. The estimation results in Table 3 show that there is no significant change from those in Table 2 in terms of the coefficient size, sign and significance level of *Treat* × *Post*.

Modifying the PSM matching method. To avoid the impact of the matching method employed in the PSM model estimation to address the sample selection problem, this study adopts nearest neighbour matching using caliper and kernel matching methods to process the samples and re–estimates the model using the processed data; the results are presented in Table 3. The significance of the coefficient of *Treat* × *Post* doesn't change significantly from the baseline regression results, further validating the robustness of the initial findings.

Placebo test. To test whether the policy effects derived above were driven by unobservable factors at the country–product–year level, a placebo test is conducted using random assignment of mutual GI recognition products (Cai et al., 2016). Ten products are randomly selected as the treatment group, and it is assumed that these products are mutually recognised GI products and the remaining products are non–mutually recognised products, constructing 'pseudo' treatment and control groups. The quality improvement of China's exported agricultural products is regressed 1,000 times as an explanatory variable, and the estimated coefficient of *Treat* × *Post* in column (6) of Table 3 is insignificant, indicating that the baseline regression results are robust.

Endogeneity test. Considering that firms may upgrade the quality of exported agricultural products to obtain mutual GI recognition, a potential two–way causality problem emerges. This study uses two–stage least squares (2SLS) to test the impact of mutual GI recognition on upgrading the quality of exported agricultural products. Referencing Chen and Mattoo (2008) and Raimondi et al. (2020), GI endowment and agricultural export value are significant criteria for selecting pilot products for mutual GI recognition, and crucial factors for policymakers to focus on. Therefore, this paper uses the average number of GIs and the value of agricultural exports that share the same HS2 digit code as instrumental variables (IVs) for the mutual GI recognition pilot, presenting the results of the two–stage regression in Table 4.

The results in the first stage regression indicate that the same HS2 digit code GI endowment and agricultural export value can significantly influence the choice of mutual GI recognition products, confirming that HS2 digit code GI endowment and agricultural export value satisfy the IV correlation assumption. The results of the two–stage regression remain consistent with the baseline results, indicating that mutual GI recognition improves the quality of exported agricultural products after accounting for endogeneity. The KP–LM statistic and the Cragg–Donald Wald F statistic show that the HS2 digit code GI endowment and the value of agricultural exports are neither unidentifiable nor over–identifiable, given the same endogenous IVs. In summary, the IV results did not significantly change the conclusion that mutual GI recognition improves the quality of exported agricultural products, considering the presence of bidirectional causality in the regression results, once again validating the robustness of the conclusion that mutual GI recognition improves the quality of exported agricultural products.

Heterogeneity test

Heterogeneity of GI endowment in importing countries. In general, consumers in countries with high GI endowment prefer

Table 3 Robustness tests.

	Replacement of Dependent Variable	Sample tail Reduction	Sample Truncation Treatment	Modification of the PSM Matching Method		Placebo Test
				Nearest Neighbour Matching within the Caliper	Nuclear Matching	
	dum_quality	*delt_quality*	*delt_quality*	*delt_quality*	*delt_quality*	*delt_quality*
	(1)	(2)	(3)	(4)	(5)	(6)
Treat × Post	0.0328***	0.9368***	1.0384***	0.2758***	0.9534***	−0.0006
	(8.06)	(4.36)	(4.53)	(11.46)	(13.75)	(−1.23)
SPS	−0.0098	−0.0010***	−0.0015***	0.0589***	−0.0957***	0.0073***
	(−1.30)	(−8.95)	(−10.53)	(6.51)	(−37.21)	(5.61)
open	1.5750***	0.3176***	0.2582***	0.0568***	0.1549***	0.2142***
	(5.91)	(4.20)	(3.23)	(6.10)	(6.75)	(6.72)
pgdp	1.1588***	0.8062***	0.8023***	0.0401***	0.1938***	0.2042***
	(12.67)	(31.02)	(28.92)	(38.58)	(7.85)	(18.45)
exchange	−0.0908	−0.2158***	−0.2146***	−0.3298***	−0.2236***	0.8718***
	(−1.07)	(−8.99)	(−8.38)	(−12.13)	(−8.75)	(9.54)
endowment_diff	0.0047	0.0645***	0.0658***	0.0006***	0.0012***	0.0924***
	(0.44)	(21.38)	(20.22)	(10.85)	(9.91)	(9.05)
cons	1.1585	1.1004***	1.1625***	−4.3093***	−10.0150***	1.2626***
	(1.23)	(4.10)	(3.97)	(−42.28)	(−36.61)	(10.82)
Firm—Year Fixed Effect	YES	YES	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES	YES	YES
R^2	0.0021	0.0181	0.0186	0.0832	0.0787	0.0076
N	133785	127095	132536	157832	142878	133785

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

Table 4 Results of the endogeneity test.

	HS2 GI Endowment		Agricultural Exports Value	
	First stage	Second stage	First stage	Second stage
	(1)	(2)	(3)	(4)
GI endowment	0.0562***			
	(14.73)			
export_value			0.2281*	
			(1.91)	
Treat × Post		0.0766***		0.3422***
		(14.71)		(3.28)
Controls	YES	YES	YES	YES
Firm—Year Fixed Effect	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES
N	133785	133785	133785	133785
KP—LM	683.82***		835.90***	
Cragg—Donald Wald F	135.74	121.20	392.89	506.89

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

agricultural products with good quality and high safety. According to the classification of importing countries' GI endowment, the UK, France, Spain and Italy are defined as countries with high GI endowment, while the remaining EU countries are defined as having low GI endowment; thus, sub–sample regressions are conducted. Table 5 indicates that the effect of GI mutual recognition on export quality is greater in countries with high GI endowment. In such countries, the more familiar the consumers are with GI products, the more they recognise the quality of GI products and the higher the price they are willing to pay for products with greater impact of GI on exports. When exporting mutual GI recognition products to countries with a high GI endowment, exporters have more motivation and stronger incentives to improve the quality of exported agricultural products to meet the high–quality demands of consumers in countries with a high GI endowment.

Heterogeneity of export firms. Export firms' scale of production and the distance between exported agricultural product quality and the world quality frontier are crucial factors influencing mutual GI recognition between China and the EU on the quality upgrading of exported agricultural products. Based on data availability, this study uses two indicators to examine the heterogeneity of agricultural firms, including the aforementioned scale of firms' export products (*scale*) and the distance between the quality frontier of firms' exported agricultural products (*frontq*). Specifically, the scale of firms' export products (*scale*) examines the proportion of export products of firms in the HS2 digit code in the year before mutual GI recognition, employing a panel quantile regression model with three quantile points of 10%, 50% and 90 to explore the impact of mutual GI recognition on export quality at different quantile points. The study also uses the distance of the world quality frontier from the quality of exported agricultural products (*frontq*), where a larger ratio represents a greater distance from the quality frontier of mutually

Table 5 Results of the test for heterogeneity of GI endowment in importing countries.

	GI Endowment Environment of Importing Country		Heterogeneity in the Scale of Production of Firm			Product Quality Frontier Distance
	High Endowment Country	Low Endowment country	$q = 10\%$	$q = 50\%$	$q = 90\%$	
	delt_quality	*delt_quality*	*delt_quality*	*delt_quality*	*delt_quality*	*delt_quality*
	(1)	(2)	(3)	(4)	(5)	(6)
Treat × *Post*	1.6201***	0.3544***	0.0794	0.2284***	0.9934***	0.1339***
	(4.94)	(4.39)	(1.26)	(11.15)	(3.29)	(4.97)
frontq						−0.2147***
						(−8.94)
Treat × *Post* × *frontq*						−0.0021***
						(−2.46)
SPS	−0.0025***	−0.0653***	−0.0002***	−0.0095***	0.1621***	0.0645***
	(−14.28)	(−12.71)	(−9.83)	(−35.07)	(40.54)	(21.39)
open	0.2175***	0.3701***	0.0140***	0.1308***	0.5293***	0.3137***
	(10.11)	(2.92)	(13.19)	(18.23)	(5.00)	(4.14)
pgdp	0.0652***	0.0001	−0.0001	0.0313***	0.7465***	0.8032***
	(13.42)	(0.09)	(−0.24)	(12.74)	(20.64)	(30.89)
exchange	−0.5342	−0.2035***	−0.0048***	−0.0302***	0.1221***	−0.0010***
	(−1.50)	(−5.14)	(−14.27)	(−13.16)	(3.61)	(−8.69)
endowment_diff	0.3199***	0.8912***	0.0005***	0.0001***	0.0002	0.0026***
	(8.40)	(24.11)	(12.44)	(11.98)	(1.29)	(3.54)
cons	−1.2837**	0.7763*	0.0457***	0.2733***	−2.0527***	1.0825***
	(−1.96)	(1.74)	(12.17)	(10.73)	(−5.47)	(4.04)
Firm—Year Fixed Effect	YES	YES	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES	YES	YES
R^2	0.0258	0.0178	0.0013	0.0080	0.0363	0.0182
N	30016	103769	133785	133785	133785	133785

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

recognised GI agricultural products. A higher ratio indicates further distance from the quality frontier and lower quality agricultural products.

Table 5 presents the results of the test of mutual GI recognition between China and the EU in terms of the border distance between firms of different production scale and product quality. For firm production scale, the regression coefficients in columns (3), (4) and (5) of Table 5, *Treat* × *Post* are insignificant at the 10% quantile position and significantly positive at 50% and 90% quantile positions, indicating that mutual GI recognition promotes quality upgrading more significantly for larger firms. For the distance of firms' product quality frontier, the regression coefficient of the product quality frontier distance (*frontq*) in column (6) is significantly negative, indicating that the closer the distance between firms' exported agricultural product quality and the world quality frontier, the more conducive to exported agricultural product quality upgrading. Generally speaking, large scale firms with advanced technology are in advantageous positions in export competition and have a widely distributed and large number of willing consumers. Such firms can better adjust business methods and export strategies to obtain the export dividend induced by mutual GI recognition and achieve sustainable growth in export quantity and continuous improvement in export quality.

Heterogeneity of agricultural products. Differences in the factor intensity of exported agricultural products can lead to different export performance and quality levels among products with mutual GI recognition between China and the EU. This study examines several representative categories of agricultural products that have exhibited a relatively high share of exports over the years and indicate more pronounced differences in factor intensity, including vegetables and fruits, livestock products, beverages and cereal food and products.[5] Among these, vegetables (HS07), fruits (HS08) and beverages (HS22) are labour–intensive agricultural products, while meat (HS02) and cereal food and products (HS19) are water and land resource–intensive agricultural products.

The regression results in Table 6 indicate that mutual GI recognition between China and the EU has a significant effect on the export quality of labour–intensive agricultural products in which China has comparative advantages, such as vegetables, fruits and beverages, but does not have a significant effect on the export quality upgrading of livestock products, cereals and other products that are resource–intensive. As extremely competitive agricultural products, vegetables, fruits and beverages are highly differentiated and processed with less dependency on land and water resources and can be easily upgraded in terms of product type, brand, germplasm, processing, storage and transportation to promote higher quality. In contrast, for agricultural products that are relatively import–dependent, such as livestock products, cereals and other resource–intensive products, mutual GI recognition does not have a significant impact on quality upgrading due to constrained agricultural water and land resources per capita and a low level of agricultural technology.

Mechanism testing: supply-side and demand-side perspectives

Model setting. The findings above demonstrate that mutual GI recognition between China and the EU has facilitated upgrading of the quality of exported agricultural products. The next concern that arises regards the mechanism by which this process is

Table 6 Results of the test for heterogeneity of export product categories.

	Labour-Intensive	Water and Land Resource-Intensive		
	Vegetable and Fruit	Beverage	Meat	Cereal Food and Product
	delt_quality	*delt_quality*	*delt_quality*	*delt_quality*
	(1)	(2)	(3)	(4)
Treat × *Post*	1.0935***	0.0016***	−0.2918	0.6324
	(8.77)	(6.80)	(−1.10)	(1.32)
SPS	0.0903***	0.0990***	−0.1124***	0.1159***
	(26.89)	(6.60)	(−2.26)	(9.24)
open	0.5781***	−0.0396	0.2657	1.6389***
	(11.08)	(−0.29)	(0.83)	(7.46)
pgdp	0.2325***	0.3617***	0.0507	0.6683***
	(13.00)	(7.64)	(0.50)	(9.73)
exchange	0.2372***	0.1124	−0.1664	0.2070
	(11.37)	(1.21)	(0.79)	(1.62)
endowment	0.0005***	−0.3612	0.0007	0.0001
	(5.80)	(−1.12)	(1.34)	(0.23)
cons	−3.3661***	−4.1557***	1.0199	−4.8578***
	(−14.23)	(−3.87)	(0.55)	(−4.40)
Firm—Year Fixed Effect	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES
R^2	0.0240	0.0208	0.0040	0.0250
N	58935	21606	10004	13704

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

achieved. Referencing Jiang (2022), this study further investigates whether mutual GI recognition between China and the EU helps firms to upgrade export quality through specialisation agglomeration, cost-saving, domestic demand upgrading and product recognition effects, and the model is constructed as follows.

$$T_{fkjt} = \alpha + \beta' Treat_{fkj} \times Post_{fkjt} + \gamma \sum Control_{kjt} + \lambda_{ft} + \lambda_{kt} + \lambda_{jt} + \varepsilon_{fkjt} \quad (18)$$

$$Y_{fkjt} = \alpha + \beta'' Treat_{fkj} \times Post_{fkjt} + \varphi T_{fkjt} + \gamma \sum Control_{kjt} + \lambda_{ft} + \lambda_{kt} + \lambda_{jt} + \varepsilon_{fkjt} \quad (19)$$

In Eq. (18) and Eq. (19), T_{fkjt} denotes the proxies for the specialization agglomeration effect ($spec\_agglo_{fkjt}$), cost saving effect ($trade\_cost_{fkjt}$), domestic demand upgrading effect (dom_dem_{fkjt}) and product recognition effect (pro_reco_{fkjt}), respectively. $Treat_{fkj} \times Post_{fkjt} \times T_{fkjt}$ denotes the cross–product term between the GI mutual recognition dummy variables and the proxies, and the coefficients of β'' and φ are the core coefficients of interest in this paper, representing that GI mutual recognition affects the quality upgrading of exported agricultural products through the specialisation agglomeration effect, cost-saving effect, domestic demand upgrading effect and product recognition effect.

Measurement of mediating variables

Specialisation agglomeration effect. This study examines the impact of mutual GI recognition in terms of the number of new products (*def_add*)[6] and product restructuring (*def_str*),verifying the mediating effect of specialisation agglomeration. The number of new products variable is measured by the number of products exported by firms to countries affected by mutual GI recognition in the period studied. For the product restructuring variable, this study references Regmi et al. (2005) for the agricultural products definition and the classification of primary and processed agricultural products,[7] using the proportion of processed agricultural products in total exports as a measure.

Cost-saving effect. This study examines the cost-saving effect in terms of the number of export destinations (*imp_num*) and trade costs (*exp_cost*). The former is measured by the number of destination countries of the firm's exports, while the latter is measured by fixed trade costs,[8] referencing Zhang et al. (2020), with the following formula:

$$FC = \left(\frac{\prod_i P_i \prod_j P_j}{t_{ii} t_{jj}}\right)^{\frac{1}{2}} = \left(\frac{X_{ii} X_{jj}}{Y_w}\right)^{\frac{1}{2\rho-2}} \quad (20)$$

where X_{ii} and X_{jj} denote the domestic sales of country i and country j respectively, and X_{jj} represents the sum of incomes of all countries, ρ denotes the product substitution elasticity, based on a study by Shi (2010), which sets the trade cost elasticity to 8.

Domestic demand upgrading effect. In this study, the quality of domestic market demand (*domdem_qua*) is used to measure the domestic demand upgrading effect. In the context of globalisation, referencing Dai et al. (2017), we use the market divergence between domestic consumption and exports to measure the quality of domestic consumption demand.

$$DI_{ih} = \frac{con_{ih}}{\sum_i con_{ih}} \times \frac{\sum_i \exp_{ih}}{\exp_{ih}} \quad (21)$$

where con_{ih} and exp_{ih} are respectively the consumer demand and export value of industry (HS4 code) h in country i, and $\sum_i con_{ih}$ and $\sum_i exp_{ih}$ are respectively the total consumer demand and total export value of the EU country industry (HS4 code) h. DI_{ih} indicates the degree of divergence between the domestic consumer market and the export market structure of country i's industry (HS4 code) h, with a larger DI_{ih} indicating a larger domestic consumer market relative to the EU market size.

Product recognition effect. Import demand elasticity (*imp_elas*) is used to measure the product recognition effect. The price elasticity of demand is an indicator of the sensitivity of quantity

demanded to price changes. Referencing Krishnamurthi and Raj (1991), this study analyses the price elasticity of China's agricultural exports using a double log–linear regression model, which is constructed as follows:

$$lnY_{fkjt} = \beta_1 + \beta_2 lnX_{fkjt} + \beta_3 lnpgdp_{jt} + \varepsilon_{fkjt} \quad (22)$$

Where Y_{fkjt} is the quantity of product k exported by firm f to country j in year t and X_{fkjt} is the price of firm f exporting product k to country j in year t; β_2 is the price elasticity of China's agricultural exports. Given the availability of data and the completeness of the model, GDP per capita ($pgdp_{jt}$) of the export destination country is introduced as a control variable. A lower export price elasticity means that the quantity demanded varies less with price, and even if the price of a GI product is relatively high, consumers are willing to pay a higher price and the impact on quantity demanded is smaller.

Mediating mechanism test

Supply side: specialisation agglomeration and cost-saving effects. The results for the specialisation agglomeration and cost-saving effects of mutual GI recognition are presented in Tables 7 and 8. For the specialisation agglomeration effect, the impact of mutual GI recognition on the number of new products is significantly negative, and the impact of the number of new products on quality improvement is also significantly negative. The impact of GI mutual recognition on product structure is significantly positive, and the impact of product structure upgrading on export quality is also significantly positive. This suggests that GI mutual recognition promotes export quality upgrading by narrowing the product range and upgrading the product structure, validating H2. Mutual GI recognition encourages firms to standardise and specialise production, optimise resource allocation by improving production technology and narrowing the product range, advance production efficiency and improve the quality of exports. For example, as a pilot list product of mutual GI recognition between China and the EU, Shaanxi apples have taken a characteristic development path of high–standard production management. In Shaanxi Province, Luochuan County uses standardised orchard design, production and quality inspection to develop product quality specifications in terms of technical requirements, production areas, packaging, transport and storage, and to promote the apple industry as having high development standards. In 2021, 530,000 acres of orchards in the county passed the national green food raw material production demonstration base certification, and 130,000 acres of export–registered orchards and 68,000 acres of organic apple production bases were identified.[9]

For the cost-saving effect, the impact of mutual GI recognition on the number of export destinations is significantly positive, and that of the number of destinations on export quality upgrading is also significantly positive. The impact of mutual GI recognition on trade costs is significantly negative, and the impact of trade costs on export quality upgrading is also significantly negative. This suggests that mutual GI recognition between China and the EU promotes export quality upgrading by reducing trade costs and increasing the number of export destinations in the EU, validating H3. Reduced trade costs make it easier for firms to enter the EU market and increases the number of EU export destination countries, which helps firms to alter export destinations from non–mutual recognition countries to mutual GI recognition countries and from low to high endowment

Table 7 Results of the mechanism test for the specialization agglomeration effect.

	Number of New Products		Product Structure Upgrading	
	def_add	*delt_quality*	*def_str*	*delt_quality*
	(1)	(2)	(3)	(4)
Treat × Post	−0.0984*	0.9391***	0.8175***	0.7512***
	(−1.80)	(4.38)	(9.59)	(6.12)
def_add		−0.0263***		
		(−3.54)		
def_str				0.0206***
				(48.81)
SPS	0.0005	0.0645***	0.0072***	−0.1887***
	(0.44)	(21.38)	(6.00)	(−4.36)
open	0.1575***	0.3145***	0.2458***	0.0496***
	(5.91)	(4.16)	(8.17)	(28.76)
pgdp	0.1159***	0.8031***	0.2151***	0.3619***
	(12.67)	(30.88)	(20.84)	(24.31)
exchange	−0.0091	−0.2154***	−0.0922***	−0.0254*
	(−1.07)	(−8.97)	(−9.66)	(−1.85)
endowment	0.0003***	0.0010***	0.0004***	0.0001*
	(8.06)	(8.99)	(9.56)	(1.88)
cons	0.1159	1.0944***	1.1980***	−1.3759***
	(1.23)	(4.08)	(11.25)	(−8.96)
Firm—Year Fixed Effect	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES
R^2	0.0021	0.0182	0.0076	0.6786
N	133785	133785	133785	133785

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

Table 8 Results of mechanism test for cost saving effect.

	Number of Export Destination countries		Trade Cost	
	imp_num	*delt_quality*	*exp_cost*	*delt_quality*
	(1)	(2)	(3)	(4)
Treat × Post	0.0634***	0.0206***	−0.1315***	0.0054***
	(8.57)	(50.08)	(−6.39)	(17.79)
imp_num		0.4980***		
		(21.35)		
exp_cost				−0.0514***
				(−2.39)
SPS	0.0037***	0.1238*	0.6853***	1.1109***
	(35.65)	(1.88)	(27.49)	(24.35)
open	0.1544***	0.0019***	−1.3091***	−0.9281***
	(19.28)	(4.36)	(−20.64)	(−8.07)
pgdp	0.0006***	0.0005***	0.2020***	1.2981***
	(16.08)	(28.73)	(89.94)	(19.93)
exchange	−0.0534***	−0.0002*	0.0023***	−0.1794***
	(−5.52)	(1.80)	(8.50)	(−76.23)
endowment	0.0385***	−0.5298***	0.0014***	0.0004***
	(4.27)	(−5.41)	(36.46)	(35.43)
cons	1.4931***	10.4436***	4.0519***	3.7885***
	(17.15)	(10.57)	(17.35)	(15.97)
Firm—Year Fixed Effect	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES
R^2	0.3953	0.4362	0.3351	0.3235
N	133785	133785	133785	133785

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

countries. Mutual GI recognition also reduces 'export delay' time and firms' 'export tentative' practices, encouraging firms to change from tentative small–scale exports to normal–scale exports, which accelerates the speed of entry into export markets and increases export volume (Qi et al., 2015). The EU has higher product standards, inspection and quarantine requirements and business registration and certification standards; therefore, firms targeting the EU market may confront more competition and higher requirements in terms of product quality, product design and production processes, which could compel firms to increase investment in research and development, improve the level of innovation and further enhance the quality of agricultural exports.

Demand side: domestic demand upgrading and product recognition effects. The test results of the domestic demand upgrading and product recognition effects of mutual GI recognition are presented in Table 9. Regarding the domestic demand upgrading effect, the effect of mutual GI recognition on demand quality is significantly positive, and demand quality is also significantly positively correlated with export quality, indicating that mutual GI recognition promotes export quality upgrading by upgrading domestic demand quality, validating H4. When the quality of local demand is improved, according to the theory of demand hierarchy fit, firms will compete to produce high–quality products, and when high–quality demand reaches a certain local density, the increased scale of high–quality demand will exert a centripetal force on the local region, exerting a local market effect (Yu and Yu, 2019). As mutual GI recognition between China and the EU continues to progress, GI agricultural products are cultivating a more stable consumer base in the market. At the same time, rural e–commerce has also opened new sales channels and expanded purchasing channels for GI products, shortened consumers' purchasing time and improved the influence of GI agricultural products. The expanded demand for high–quality products generated by mutual GI recognition has attracted more producers to the market for high–quality products.

Regarding the product recognition effect, since mutual GI recognition has a significant negative effect on increasing the price elasticity of demand in the destination country; moreover, the price elasticity of demand is also significantly negative for quality upgrading, the product recognition effect of mutual GI recognition is verified, thus confirming H5. Mutual GI recognition sends effective signals to consumers in terms of product quality, significantly reduces perceived consumer risk, increases product confidence and gives mutually recognised products a significant competitive advantage in the EU market, which motivates firms to upgrade quality. According to European consumer opinion surveys, 40% of EU consumers are willing to buy a product with guaranteed geographical origin even if the price is 10% higher than the average product (Gangjee, 2017). The quality and safety information behind mutual GI recognition improves product recognition and consumer willingness to buy, shapes the differentiated competitive advantage of distinctive agricultural products and negates previous stereotypes of low prices for Chinese agricultural products, restoring the competitive advantage of Chinese agricultural products.

Table 9 Results of mechanism tests for domestic demand upgrading and product recognition effects.

	Domestic Demand Quality		Import Demand Elasticity	
	domdem_qua	*delt_quality*	*imp_elas*	*delt_quality*
	(1)	(2)	(3)	(4)
Treat × Post	0.0522***	0.0938	−0.1310***	−0.0167
	(7.71)	(0.46)	(−8.03)	(−0.23)
domdem_qua		1.4342***		
		(19.35)		
imp_elas				−0.1624***
				(−43.57)
SPS	0.0012***	0.0652***	0.0103***	−0.0007
	(13.70)	(24.22)	(47.65)	(−0.72)
open	0.0478***	0.1710***	0.0913***	0.1753***
	(20.16)	(2.40)	(15.97)	(6.93)
pgdp	0.0332***	0.6229***	0.0594***	0.1136***
	(40.89)	(25.46)	(30.42)	(13.14)
exchange	−0.0094***	−0.0699***	−0.0393***	−0.0487***
	(−12.33)	(−3.07)	(−21.57)	(−6.02)
endowment	0.0001***	0.0008***	0.0001***	0.0003***
	(33.10)	(7.48)	(6.99)	(7.34)
cons	0.1902***	−0.1013	0.5209***	2.0647***
	(22.58)	(−0.40)	(25.67)	(21.08)
Firm—Year Fixed Effect	YES	YES	YES	YES
Product—Year Fixed Effect	YES	YES	YES	YES
Country—Year Fixed Effect	YES	YES	YES	YES
R^2	0.0060	0.0186	0.0472	0.0135
N	133785	133785	133785	133785

Notes: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent, respectively.

Conclusion

Research conclusion. Upgrading the quality and trade added value of China's exported agricultural products is crucial to establishing new competitive advantages for agricultural exports, building a strong trading and quality country and advancing high–quality agricultural development.

Based on the theoretical analysis of the impact mechanism of GI mutual recognition on the quality upgrading of exported agricultural products, this paper constructs a multi–time point difference–in–differences model based on Chinese customs data from 2000 to 2016 to empirically test the impact effect and mechanism of mutual recognition of geographical indications between China and the EU on the quality upgrading of China's exported agricultural products. The study finds that: (1) The mutual recognition of geographical indications between China and the EU effectively improves the quality of exported agricultural products, and this result still holds after a placebo test, a counterfactual test and several robustness tests; (2) The heterogeneity study finds that the effect of the mutual recognition of geographical indications on quality upgrading is greater for countries with high geographical indication endowment, for quality frontier and large and medium–sized firms, and for labour–intensive products; (3) The mechanism analysis finds that the mutual recognition of geographical indications between China and the EU improves product concentration and reduces trade costs on the supply side through the specialization agglomeration effect and the cost saving effect, which in turn promotes the quality upgrading of exported agricultural products; on the demand side through the domestic demand upgrading effect and the product recognition effect, which improves the level of domestic demand and stimulates import demand, thus realizing the quality upgrading of exported agricultural products.

Policy recommendations. To further enhance the influence of mutual GI recognition on promoting the quality upgrade of exported agricultural products, this study proposes three relevant policy

recommendations. First, based on the characteristics and features of agricultural products, the economic development of trading partners and GI certification, mutual GI recognition negotiations with other countries (regions) in the world should be strategically strengthened, including countries along the One Belt One Road and Regional Comprehensive Economic Partnership member countries and other relevant economic constructs to transform China's current dilemma of strong quantity but poor quality of agricultural exports and achieve export quality upgrade through the incentive mechanism of high–quality product supply and demand.

Second, further improve GI protection systems and strengthen oversight of the quality of GI products, strictly enforcing the certification of GI protection, conducting random inspection for certified products and decertifying those that fail and shifting GI certification from the pursuit of quantity to quality improvement. Policies should promote the integration of new–generation information technology such as artificial intelligence and big data into GI quality management to accelerate the development of a GI quality assurance system based on digitisation, networking and intelligence to effectively support the high–quality development of GI products.

Third, the government should cooperate with the overall layout of domestic agricultural supply–side reform, seize the opportunity of mutual GI recognition between China and the EU; refer to the international quality benchmarks of the same industry to formulate agricultural technical specifications and local standards for production, processing, storage and transportation of agricultural products, promote market access and quality tracking systems and advance the standardisation of agricultural production and upgrade agricultural products with high demand.

Data availability

The data that support the findings of this study are available from the Experimental Teaching Centre for Intelligent Business of East China University of Science and Technology, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from authors upon reasonable request and with permission of the Experimental Teaching Centre for Intelligent Business of East China University of Science and Technology.

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Notes

1 See 'Famous Specialities White Skinned Garlic', http://www.jinxiang.gov.cn/art/2022/8/11/art_18087_1305203.html.

2 The 10 products that China has obtained the EU GI recognition include Longkou Vermicelli (approved on 30th October, 2010), Guanxi Honey Pomelo (approved on 11th May, 2011), Lixian Hemp Yam (approved on 11th May, 2011), West Lake Dragon Well Tea (approved on 11th May, 2011), Shaanxi Apple (approved on 11th May, 2011), Jinxiang Garlic (approved on 1st November, 2011), Zhenjiang Balsamic Vinegar (approved on 13th June, 2012), Yancheng Lobster (approved on 9th August, 2012), Pinggu Big Peach (approved on 26th October, 2012) and Dongshan White Asparagus (approved on 18th November, 2012). If the '10 + 10' GI product mutual recognition pilot product list determined by China and the EU in March 2011 is used as the time point for standard double difference model estimation, the 'one size fits all' approach may cause estimation deviation. The multi–time point DID model can reflect the current circumstances of the mutual recognition of GI products between China and the EU and accurately estimate the trade effect of the mutual recognition of GI.

3 In terms of the collection and collation of GI product data, the former State Administration for Industry and Commerce of China (now the State Intellectual Property Office), the former General Administration of Quality Supervision, Inspection and Quarantine of China (now the State Intellectual Property Office) and the former Ministry of Agriculture of China (now the Ministry of Agriculture and Rural Affairs of China) all have the right to authenticate and approve GI. Considering the integrity of the data, this study conducts a comprehensive collection of GI product data for three departments. With the help of the Standard Classification of International Trade (Fourth Edition) and the Customs Import Tariff (2007 Edition), the cumulative number of GI products with the same HS2 digit code in the same place of production over the years can be obtained.

4 During the sample period, there were 28 EU member states: Austria, Belgium, Bulgaria, Cyprus, Croatia, the Czech republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United–kingdom.

5 HS02 (Meat), HS03 (Aquatic products), HS04 (Dairy products), HS07 (Vegetable), HS08 (Fruit), HS09 (Coffee, tea and spices), HS12 (Oilseeds and sugar), HS19 (Cereals, grain flour) and HS22 (Beverages, wine and vinegar), which account for over 70% of China's total agricultural exports and are highly representative.

6 As the sample period of the baseline regression is limited to 2000 to 2016, it is not possible to determine whether firms at the beginning (end) of the period exported to that market in the year before (after), so the regression only identifies the sample of firms from 2001 to 2015. Fixed effects include product year and destination year fixed effects, with error terms clustered at the HS6–digit code product level.

7 According to Regmi et al. (2005) on the definition of agricultural products and the classification of primary and processed agricultural products, primary agricultural products mainly include coffee, cereals, soya beans and cotton. The corresponding HS codes in the sample of this paper are HS09011, HS0902 and HS0903.

8 In terms of trade costs, there are two types of trade costs that a country must overcome in order to export its products to another country: variable trade costs and fixed trade costs. Of these, fixed trade costs refer to the costs of processing trade–related paperwork, communication costs, the costs of taking on uncertain risks, and monitoring costs.

9 See 'Focusing on Apples to Lead and Revitalise the Countryside', http://www.lcx.gov.cn/jdhy/zxft/1566675695390814209.html.

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WQ contributed to the writing—original draft preparation, the writing—review and editing, and the funding acquisition; YD carried out the conceptualization, the writing—review and editing, supervision, and funding acquisition. YL performed the writing—review and editing, methodology, data analysis and software. All authors have revised the paper for important intellectual content and have read and agreed to the present version of the paper.

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The authors declare no competing interests.

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