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ORIGINAL ARTICLE

Does the internationalisation of China's agri-food standards affect export quality upgrading?—Evidence from firm-product-level data

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Abstract

China attaches importance to the development of standards in agri-food sectors, especially the harmonisation of national standards with international standards. Our study matches agri-food product standards and firm-product customs data for the period from 2000 to 2015. We perform an empirical analysis using the 'distance to the frontier' model to identify the effects of the internationalisation of China's agri-food product standards on the quality upgrading of firms' exported products. The results suggest that when Chinese standards are harmonised with international measures, there is a significant positive impact on quality upgrading. In addition, this international standards–quality relationship is nonmonotonic; that is, firm-level products that are far from the quality frontier are more likely to upgrade quality in response to an increase in standards. Conversely, national standards have not demonstrated good trade performance and have no significant quality-promoting effect on firms' export products. These results are robust to various checks. Moreover, the heterogeneous effects further suggest that the positive correlation between international standards and quality upgrading is even stronger for modified versions of international standards, in smaller-sized firms and foreign-invested firms. Finally, the quality upgrading effects of international standards induce an increase

in both the extensive and the intensive margins of firms' exports.

KEYWORDS
agri-food standards, China's agri-food sector, distance to the frontier, quality upgrading

JEL CLASSIFICATION
F13, F14, Q18

1 | INTRODUCTION

Agri-food safety incidents have always been an issue of great concern in China, including the abuse of food additives as well as contamination by pathogenic micro-organisms, pesticides, veterinary drug residues and heavy metals. These agri-food safety problems have affected the country's food safety status and have adversely affected China's agri-food trade and national reputation. According to the reports of the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), 1619 batches of China's exported agri-food products were rejected in the United States, Japan, European Union (EU), South Korea, Canada and Australia in 2016. The 'Annual Report on China's Technical Trade Measures in 2017' showed that, in 2016, 34.1% of China's export enterprises were affected by foreign technical trade measures, leading to direct losses and new costs exceeding 500 billion yuan.

To eliminate the negative effect of low quality on agri-food product exports and reduce the quality gap with developed countries, China has intensified its efforts in improving its agri-food product standards systems. Amongst the sections of China's eleventh Five-Year Plan on standardisation, agriculture and food safety are listed as key areas of standardisation, and China's standardisation strategy encourages the adoption of international standards. In addition, the plan to enhance high-quality development of the agricultural sector of China (2018–2022) explicitly requires accelerating the coordination of national and international standards and the promotion of advanced international standards on a full-scale basis in suitable areas. In theory, the application of international food standards is considered to be an effective practice to address food safety and quality issues. Standards could increase the transparency of the production supply chain and the level of quality and safety of products by defining product characteristics and specifying quality levels to exclude the production of low-quality products and lead agricultural products to higher stages of the quality ladder (Dequiedt, 2018). However, the adoption of standards brings larg compliance costs to enterprises, including the introduction of advanced equipment, personnel and management experience, and therefore can restrict the ability of enterprises to improve product quality. In particular, unlike national standards proposed by domestic industry associations or leading enterprises according to domestic production conditions, international standards are mostly based on those of developed countries and are generally more stringent than national standards already in place in China. In order to meet the requirements set by international standards, Chinese enterprises often face higher compliance costs.

Do standards significantly boost the quality upgrading of China's agri-food exporters? Have the Chinese government's great expenditures on coordinating agri-food product standards with international standards achieved the expected result of the quality upgrading? These are the central questions this paper seeks to answer. The paper consequently uses matched data consisting of agri-food product standard data and firm-product customs data for the period from 2000 to 2015 to perform empirical testing of the effect of China's agri-food product standards on the quality upgrading of firms' export products. We find that, in general, more standards induce firms to upgrade export product quality, and this positive effect of Chinese standards is larger when they are harmonised to international measures. We also find that the effect of international standards on quality upgrading is nonmonotonic, meaning that firm-level products far from the quality frontier are more likely to upgrade quality in response to an increase in international standards, whilst the opposite holds for those close to the frontier. In addition, we conduct further heterogeneity analysis of these effects across different international standards and firms to thoroughly consider the actual implementers of the standards and firm behaviours. The estimation shows that modified versions of international standards and firms that are foreign-invested or smaller-sized are active in product quality upgrading. Finally, we explore the performance of different standards in the standards–trade relationship as a complement to the standards–quality relationship. We find evidence that international standards boost trade at the extensive and intensive margins and act as a catalyst in trade. Thus, the internationalisation of Chinese standards not only promotes the quality upgrading of agri-food firms' export products but also expands the scope of export destinations and increases market share.

Our research makes three contributions to the literature. Firstly, many studies investigate the effects of standards imposed by developed countries and just consider developing countries only as typically international 'standard-takers' (e.g. Curzi et al., 2020; Hu & Lin, 2016; Murina & Nicita, 2017). Evidence on the effects of standards imposed by developing countries on quality upgrading at the firm level is rare. Secondly, previous studies have mainly focussed on standards used by importing countries (e.g. Curzi et al., 2015; Eum et al., 2018; Fernandes et al., 2019), whereas few studies have focussed on the standards implemented by the exporting country for its produced goods. In this article, we study the impact of Chinese standards on the quality of its own agri-food product exports. As a developing country, China's importance in the global market is gradually growing, making it a natural case study for investigating this issue. Thirdly, whilst the quality-upgrading effect of product standards has been confirmed in the literature and some studies indicate that regulatory standards can promote trade through quality upgrading (e.g. Movchan et al., 2020), we add empirical evidence on how international standards for products affect trade volume by promoting quality.

The rest of the paper proceeds as follows. Section 2 provides a brief literature review of the analysis of agri-food product standards and product quality. Section 3 discusses the institutional background of the agri-food product standards in China. In Section 4, we discuss our empirical strategy, describe in detail how we measure our dependent variables and report a detailed description of the data. We present our empirical results in Section 5. Section 6 draws conclusions.

2 | LITERATURE REVIEW

Agri-food product standards that are closely linked to the international food supply chain have become an important research area for scholars. Existing studies have mainly focussed on two aspects, that is, standards–trade relationships and standards–quality relationships.

2.1 | Standards and trade

Agri-food product standards have a mixed impact on trade; that is, standards might be protectionist, competitive or even have null effect on trade. On one hand, standards provide consumers with quality information, which reduces information asymmetry and ultimately serves to promote trade. On the other hand, standards might inhibit trade by increasing firms' compliance costs (Kim, 2021; Swinnen, 2016; Xiong & Beghin, 2014). Empirical studies have therefore largely attempted to clarify the debate concerning whether standards serve as catalysts or barriers to trade. A series of studies proved that the negative effect of compliance costs outweighs the positive effect of quality information, leading to the standards-inhibited trade effect (Fontagné et al., 2015; Fontagné & Orefice, 2018). For example, a study by Kareem et al. (2018) employing a gravity model found that standards imposed by the EU on the maximum residue limits (MRL) for fruits (mainly tomatoes exported from Africa) impede trade. Similar to Kareem et al. (2018), most existing studies focus on how agri-food standards set by developed countries affect exports in developing countries (e.g. Curzi et al., 2020; Murina & Nicita, 2017). This is because product standards are usually issued by high-income countries, and such standards are often regarded as some kind of trade barrier by less-developed countries (Hu & Lin, 2016). Several studies have also concluded that agri-food standards imposed by developed countries restrain exports from developing countries, such as Otsuki et al. (2001), Gebrehiwet et al. (2007) and Webb et al. (2018). In addition, some research has shown that agri-food product standards have no impact on trade. For example, Xiong and Beghin (2012) find that the MRL set by the EU has no significant trade impact on groundnut exports from Africa using a gravity model that considers multilateral resistance terms. The results of Disdier et al. (2008) suggest that the stringency of sanitary and phytosanitary (SPS) and technical barriers to trade (TBT) significantly reduces agricultural exports from developing countries to Organization for Economic Co-operation and Development (OECD) countries, but does not affect agricultural trade between OECD members. Nevertheless, some empirical studies suggest that the positive effect of the quality information imparted by agri-food product standards is greater than the negative effect of compliance costs, implying that standards ultimately promote exports (Andersson, 2019; Cadot et al., 2018; Mangelsdorf et al., 2012). This is verified by ample empirical evidence examining the impact of standards on China's agricultural exports (Dou et al., 2015; Ishaq et al., 2016). Recent research has begun to emphasise the heterogeneous effects related to the size of the exporters of standards on trade, and the different categories of standards and the development status of the destination countries. (Anders & Caswell, 2009; Hejazi et al., 2022; Wilson et al., 2003). For instance, Shepherd and Wilson (2013) find that non-ISO (International Organization for Standardization) standards have greater inhibiting effects on trade than ISO standards, and they have the greatest inhibiting effect on primary product exports from developing countries. Fiankor, Haase, and Brummer (2021b) suggest that the trade of countries with large trade volumes is less affected by standards than that of countries with small trade volumes. As firm-level data have become available in recent years, many studies have begun to examine the effect of agri-food standards on trade at the firm-level (e.g. Curzi et al., 2020; Kruse et al., 2021). It is found that compared with larger exporting firms, smaller firms are more affected by restrictive standards in their market entry and exit decisions and more prone to exit the market (Fernandes et al., 2019).

2.2 | Standards and quality

Product standards not only affect trade flows but also influence product quality directly. With the growing importance of quality as an essential feature of products in the food sector, recent research on how standards affect product quality has received increasing attention. In general, standards can serve as an important quality signal in trade and can help overcome the 'lemon' problem, that is incomplete and asymmetric information about food products. From this aspect, standards may create an incentive to improve product quality (Hudson & Jones, 2003). As shown by Olper et al. (2014), an investigation of the relationship between the diffusion of EU standards and product quality finds that the diffusion of EU food standards significantly contributed to improvements in import quality. Similarly, Raimondi et al. (2019) find that geographical indications have a positive effect on export prices, which corroborates the idea that some geographical indication products (similar to meeting high standards) are perceived by consumers as higher quality goods. Furthermore, several studies have also investigated the heterogeneous impact of standards with different degrees of restrictiveness on quality and found that only the most stringent standards result in product quality upgrading (Curzi et al., 2020; Duvaleix et al., 2021). However, standards may also harm improvements in export product quality, as stricter standards impose higher compliance costs (Movchan et al., 2020). The reason behind this may be that firms might use less expensive raw materials after assessing the increases in production costs caused by the standards, which ultimately causes product quality to decrease (Hu & Lin, 2016). Using prices as a proxy for quality, Fernandes et al. (2019) find a negative but statistically insignificant effect of MRL difference. This is contrary to their *a priori* expectation that stricter MRLs in the destination country lead to higher imported product quality. Considering competition and market power, Fiankor, Curzi, and Olper (2021a) found that MRL standards have a null effect on quality upgrading. The implied explanation is that MRLs are mandatory public standards and, unlike private quality standards (e.g. Fairtrade or Organic), are not directly communicated to consumers. Quality, as measured by consumer behaviour, does not show an empirically meaningful trend of change. In addition, Eum et al. (2018) introduce standards into a model of competition and innovation, which shows that the effect of stricter standards on quality upgrading varies nonmonotonically. It can therefore be seen from previous studies that the question of whether an increase in standards is beneficial or detrimental to improving export product quality has not been definitively answered and requires further empirical testing.

3 | INSTITUTIONAL BACKGROUND

3.1 | The standardisation process of China's Agri-food product

The development of China's agri-food product standardisation is very slow.[1] It was not until the promulgation of the Standardization Law in 1988 that China's legal system for standardisation began to be established, which includes the implementation of the Agricultural Standardization Management Measures in 1991. In 1999, China's Ministry of Agriculture and Ministry of Finance launched a special programme supporting the revision of approximately 350 agricultural industry standards each year. Since then, the number of standards related to agri-food safety and technology has gradually increased. After entering the World Trade Organization (WTO), the construction of China's agricultural and food product standards system developed at a rapid rate. In 2006, the Law on Quality and Safety of Agricultural Products was introduced and formally implemented, making China's agricultural and food product standards more refined and specific. Successively, the Food Safety Law was promulgated and implemented in 2009, the Measures for the Administration of National Food Safety Standards was promulgated and implemented in 2010, and in 2015, the relevant administrative agencies issued the Measures for the Administration of Food Safety Sampling and Inspection and the Measures for the Administration of Food Production Licensing. Furthermore, under policies designed to make China a country recognised for high-quality products, the government has continuously revised the Regulations on the Management of National Standards and the Management of Enterprise Standardization to better improve current standardisations.

[1]According to the definition of *Standardized Working Guidelines*, a standard is a normative document developed by consensus and approved by a recognized body, allowing for common use and reuse to obtain the best possible order within a certain range.

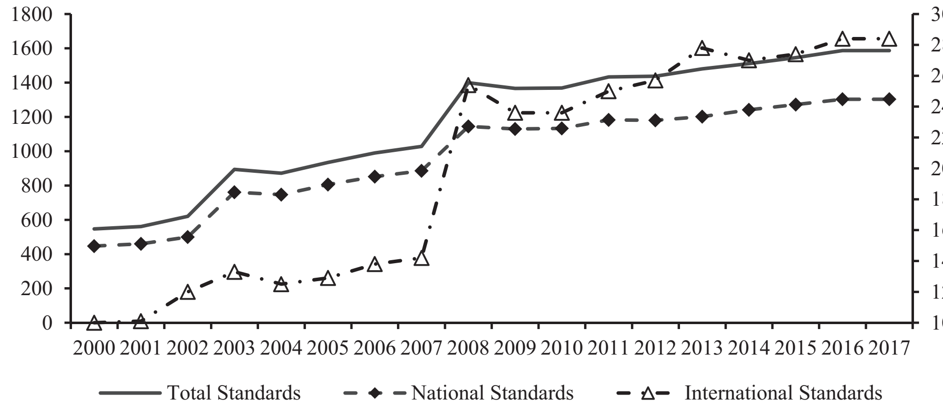


FIGURE 1 Trend graph of changes in standards. *Note*: The primary y-axis represents total standards and national standards, and the secondary y-axis represents international standards.

Since the establishment of the National Standardization Administration Committee in 2001, the development and implementation of national standards in China have themselves begun to be standardized. The number of standards related to food safety and technology has been increasing since 2000, growing in number from 650 in 2000 to 1596 in 2017, an increase of 145.5%; the number of national standards in 2017 was 1303, which is three times as many as existed in 2000, when there were 447. The trend of variations in standards is shown in Figure 1.

3.2 | The internationalisation process of China's agri-food product

The internationalisation of standards in China is called standard adoption, that is, the adoption of international standards or advanced foreign standards. The goal and practice of international standards adoption is to incorporate international or advanced foreign standards into the national standard system, particularly when developing national standards. Presently, in the field of China's agri-food products, the relevant international standards primarily involve ISO standards from the International Organization for Standardization, the OIE standards of the World Organization for Animal Health (OIE) and the Codex standards of the International Codex Alimentarius Commission (CAC). Chinese standards can be further subdivided into three types according to their degree of harmonisation with international standards: identical (IDT), meaning that a national standard is equivalent to the relevant international standard without modification or with editorial changes only; modified (MOD), meaning that a national standard is equivalent to an international standard with minor technical differences or editorial differences; and, not equivalent (NEQ), meaning that the national standards and international standards have a corresponding relationship. The Administrative Measures for the Adoption of International Standards promulgated and implemented in 2001 denotes that China would adopt only IDT and MOD, whilst NEQ is not included because of the differences in technical content and text structure between national standards and the corresponding international standards. Therefore, NEQ standards are considered national and are analysed below.

The adoption of more international standards or advanced foreign standards has been encouraged in China, and a large number of international standards have been adopted in more than 30 years of standards development. Figure 1 shows that the number of international harmonised standards for agri-food products increases from 100 in 2000 to 284 in 2017. The number of international standards accounted for only 18.4% of the total number of standards in 2017, much smaller than the 81.6% share of national standards. It is indicated that the current growth rate of the number of adopted standards is slow and that the number of international standards as a percentage of the total number of standards is still small. Moreover, from the perspective of the degree of international standard adoption, IDTs have exceeded MODs since 2009, with each trending differently; that is, IDTs account for an increasingly high proportion of the number of international standards (exceeding 50%) and have become an important part of international standards adoption. The detailed distribution of international standards for the period 2001–2017 is presented in the Figure S1 of Appendix S1. It is revealed that China tends to adopt relevant international standards directly in the process of harmonising international standards and attaches importance to the linkage with international standards.

4 | DATA AND METHODOLOGY

4.1 | Estimation strategy

We test the relationship between standards and quality upgrading in the agri-food sector using the estimation strategies suggested by Olper et al. (2014) and Curzi et al. (2015), which is the 'distance to the frontier' framework of Amiti and Khandelwal (2013). These studies find that firms close to the quality frontier are more likely to upgrade product quality in response to tariff reduction (Curzi et al., 2015; Olper et al., 2014). These strategies are derived from the analytical framework of the frontier distance model (Aghion et al., 2009), which originally describes the nexus between competition and innovation whilst introducing the concept of technological frontier distance. Although both competition and innovation are much broader concepts than the focus of our analysis, quality upgrading is one important form of innovation, and standards related to export decisions affect the competitive environment of the market (Wang et al., 2022). Moreover, this analytical framework helps us to explore the heterogeneous performance of Chinese agri-food product exporters at different frontier distances and may indirectly explore the reasons for the lack of high-quality agri-food product exporters in China. The estimation specification at the firm-destination-product-year level takes the following form:

$$\begin{aligned}\Delta quality_{fkct} = &\beta_1 DF_{fkc,t-5} + \beta_2 lnstd\_i_{k,t-5} + \beta_3 lnstd\_d_{k,t-5} + \beta_4 DF_{fkc,t-5} * lnstd\_i_{k,t-5} \\ &+ \beta_5 DF_{fkc,t-5} * lnstd\_d_{k,t-5} + \beta_6 lntar_{kc,t-5} + \alpha_{ft} + \alpha_k + \alpha_{ct} + \varepsilon_{fkct}\end{aligned} \tag{1}$$

where the subscripts f, k, c and t represent the firm, product category, export destinations and year, respectively. The dependent variable is the quality change between periods t and t-5, which is defined as $\Delta quality_{fkct} = quality_{fkct} - quality_{fkc,t-5}$ Referring to Curzi et al. (2015) and Falkowski et al. (2019), all explanatory variables are lagged by five years to reduce the potential for endogeneity concerns arising from reverse causality. Here, potential reverse causality describes the event where an association between standards and quality upgrading is not due to direct causality from standards to quality upgrading, but rather because the need for quality upgrading actually results in changes to standards (Kruse et al., 2021); that is, the government targets low-quality products with more standards for upgrading, so that quality might inversely influence standard-setting. Standard generation is a time-consuming process, as it typically takes more than five years from the proposition of a new standard to its final implementation (Blind & Jungmittag, 2005). Thus, there are no obvious reasons to expect that the level of product quality upgrading observed in a particular year would affect the number of standards observed 5 years earlier. In addition, we use firm-level data in our study. Considering the complexity involved in making sectoral standards, it is unlikely that standards are set in response to variations in the quality of a particular product exported by a firm to a destination in a given year (Mangelsdorf et al., 2012). $lnstd\_i_{k,t-5}$ is expressed[2] as the logarithm of the number of international standards; $lnstd\_d_{k,t-5}$ represents the logarithm of the number of national standards. Thus, quality growth is explained by the lagged international standards ($lnstd\_i_{k,t-5}$), the lagged national standards ($lnstd\_d_{k,t-5}$) and the two interaction terms between these two variables with the lagged distance to the frontier ($DF_{fkc,t-5} = \frac{quality_{fkc,t-5}}{maxquality_k}$). DF is the ratio of the quality of a given product to the highest quality product within the same product category, which is between zero and one. The closer the DF value is to one, the closer the product quality is to the frontier. To compare the above impact with that of the aggregate, we also introduce the total standards variable. The estimation specifications for the total standards are also similar to Equation (1), with the only change being the replacement of the explanatory variables ($lnstd\_i_{k,t-5}$ and $lnstd\_d_{k,t-5}$) with the variables that represent the sum of standards, that is $lnstd_{k,t-5}$, expressed as the logarithm of the total number of standards with five lagged periods.

The baseline specification includes an array of fixed effects for the firm-year (α_{ft}), destination-year (α_{ct}) and product (α_k) to mitigate error term bias from omitted variables causing endogeneity problems. The firm-year fixed effects control for observable and unobservable variables that vary with time at the firm (e.g. productivity, research capacity and size). The destination-year fixed effects and product fixed effects items capture year-variant, country-specific (e.g. gross domestic product [GDP], institutions) and product effects. Moreover, $lntar_{kc,t-5}$ is a control variable for bilateral tariffs[3] with five lagged periods, which accounts for any potential trade policy substitution between tariffs and standards in our estimations. ε_{fkct} is the error term that includes all unobserved factors that may affect quality upgrading, which we cluster at the firm level.

In addition, we also conduct an empirical study using a gravity-like model. Gravity-like models are frequently used to examine the effect of standards on trade volume and standards on product quality (e.g. Curzi et al., 2020; Fiankor, Curzi, & Olper, 2021a). However, since this paper emphasises examining the heterogeneous performance of firms at different frontier distances, we focus on the results of 'distance to the frontier' framework and use the results of the gravity-like model as a robustness test. The specific estimation equation is as follows and is estimated through ordinary least squares (OLS) regression:

$$\Delta quality_{fkct} = \beta_1 lnstd\_i_{k,t-5} + \beta_2 lnstd\_d_{k,t-5} + \beta_3 lntar_{kc,t-5} + \alpha_{ft} + \alpha_k + \alpha_{ct} + \varepsilon_{fkct} \qquad (2)$$

The meaning of the variables in Equation (2) is the same as in Equation (1).

4.2 | Measurement

4.2.1 | Measure of product quality

Product quality is not directly measurable; hence, existing studies use various proxies to analyse the role of product quality in trade outcomes (Schott, 2004). Early scholars used unit value as a proxy for product quality (Hallak, 2006). However, the reliability of this method has been questioned, as unit value is likely to be correlated with demand shocks and market competition (Piveteau & Smagghue, 2019). Subsequently, more research has used novel instrumental variable strategies to estimate time-varying product quality at the

[2]Given variables (Std_i_{kt} and tar_{kct}) can take the value of zero, the variables ($lnstd\_i_{k,t-5}$ and $lntar_{kc,t-5}$) have been logarithmically treated on a plus 1 basis.

[3]Bilateral tariffs are ad-valorem tariffs in the form of Most Favoured Nation (MFN) rates at the HS 4-digit level.

micro-level (Khandelwal, 2010; Manova & Yu, 2017; Piveteau & Smagghue, 2019). In this paper, we mainly estimate quality by adopting the method of Khandelwal et al. (2013). The intuition behind this approach is that conditional on price, a variety with a higher imported quantity indicates higher quality. Furthermore, for a robustness check, we also estimate quality using unit value as a proxy.

For Khandelwal et al. (2013) method, a representative consumer for a variety υ in country c has a constant-elasticity-of-substitution (CES) utility function given by $U = \left[\int_{v \in V} [\lambda(v) q(v)]^{(\sigma-1)/\sigma} dv\right]^{\sigma/(\sigma-1)}$, where $q(v)$ is the consumed quantity of v and $\lambda(v)$ is its quality, and $\sigma > 1$ is the elasticity of substitution. Assuming this preference, the demand for exports of firm f of product k (at the HS 4-digit level) in a country c at time t is given by the following demand function, obtained through the maximisation of the above utility function, under the usual budget constraint, yielding

$$q_{fkct} = \left(\lambda_{fkct}\right)^{\sigma-1} \left(p_{fkct}\right)^{-\sigma} P_{ct}^{\sigma-1}\ Y_{ct} \quad (3)$$

where p_{fkct} and λ_{fkct} are the export price and the relative quality attributed by the consumers in country c to product k, respectively, exported by firm f at time t. P_{ct} is a price index (adjusted by the demand shifter), and Y_{ct} represents the destination country income. Taking the log of Equation (3) yields the following OLS equation, which allows estimation of product quality:

$$lnq_{fkct} + \sigma lnp_{fkct} = \delta_k + \delta_{ct} + \varepsilon_{fkct} \quad (4)$$

where q denotes the export quantity. δ_k and δ_{ct} represent, respectively, product and country-year fixed effects, and ε_{fkct} is the error term. Product quality is then computed by dividing the residual by the country-industry specific elasticity of substitution minus 1, namely:

$$quality = \hat{\lambda}_{fkct} \equiv \hat{\varepsilon}_{fkct} / (\sigma - 1) \quad (5)$$

where $\hat{\varepsilon}_{fkct}$ is the residual of Equation (4) from the OLS regression. The choice of σ is vital for the estimated quality, and many studies employ various estimates of σ (Anderson & Van Wincoop, 2004). In our estimation, the destination-product (HS 3-digit) elasticity of substitutions is taken from Broda et al. (2006).[4]

4.2.2 | Measure of standard variable

Scholars generally use specific parameters of a certain standard or inventory approach to measure the stringency of agri-food standards. The former method refers to the specific indices for agri-food safety standards often used in empirical studies, including the MRL of pesticides. The lower the MRL level for pesticides, the more stringent the agri-food safety standards (Chen et al., 2008; Wei et al., 2012). However, the disadvantage of this method is that only specific products are studied, not products from one or all sectors. The latter inventory approach uses the total number of standards to measure the stringency of the standard. As Swann (2010) points out, this approach forces us to assume that all standards have equal weight, whereas, in practice, some standards are likely to be more 'binding' than others. Therefore, the validity and importance of different standards cannot

[4]Referring to Curzi and Huysmans (2022), we also use the elasticity data from Fontagné et al. (2022) as a robustness check. Note that whilst Fontagné et al. (2022) provide elasticity data at a more disaggregated level than Broda et al. (2006), this elasticity data is not country-specific. Our findings using this alternative data, presented in Table S1 of Appendix S1, remain consistent with the baseline regression results.

be distinguished with the inventory method (Swann et al., 1996). Although this inventory approach gives equal weight to all existing standards, it has been widely used in the literature due to the difficulty of measuring the intensity of standardisation (Mangelsdorf et al., 2012; Olper et al., 2014; Shepherd & Wilson, 2013). In this paper, we also use the inventory approach to measure the standard variables taken in Equations (1) and (2). However, here, the standard variables only indicate the number of standards, which does not indicate how stringent they are; that is, we estimate the relationship between the count of standards and product quality upgrading.

4.3 | Data

Our study draws on data from the following sources. The first is the China Customs data from 2000 to 2015. The data set covers export transactions information for each exporter in China, specifically including product information (classified at the HS 6-digit level), trade volume, trade value, the identity of the exporter and destinations. We use this database to calculate the quality of export products. The second data source is the Standardization Administration of the People's Republic of China (SAC), covering all standards information from 2000 to 2015. The SAC has detailed meta-information on each agri-food standard, such as product information, effective date, revocation date, version update and whether international standards have been adopted. Each standard is classified according to the International Classification of Standards (ICS) nomenclature, which allows us to match standards to trade data. For our analysis, we collect information on all agri-food standards classified by the ICS as category 67[5] during our sample period. Third, we retrieve tariff data at the HS 6-digit from the United Nations Commission on Trade and Development (UNCTAD) via the World Integrated Trading Solution (WITS) and aggregate the data to the HS 4-digit (simple) average tariffs.

Two data sets from China Customs and SAC are then combined based on HS codes and ICS codes. However, it is difficult to directly match HS 6-digit codes with ICS codes. The paper draws on the classification of Mangelsdorf et al. (2012), which covers only seven product groups that are frequently a target of strict agri-food standards and regulation. Thus, we aggregate the unit of estimation from the HS 6-digit to the HS 4-digit level. We conduct empirical analysis across the HS 4-digit level.[6] A concordance table between the ICS categories and trade data in HS codes can be seen in Table S2 of Appendix S1. Moreover, the export value and price involved in the quality measure are treated to take into account the potential outliers. The export value is deflated by the US consumer price index, whilst the export price is calculated based on the export value and volume indicators by dropping the extreme values within the 1st and 99th percentiles. Last, we remove samples with an export quantity less than or equal to 1 and a single trade value of less than US$50, and exclude products with an overall sample size of less than 100 to ensure estimation reliability and data credibility.[7]

[5]The ICS is a hierarchical classification which consists of three levels. The category 67 here, one of the first level of the ICS classification, refers to food technology. Category 67 includes 17 secondary classifications such as 67.060 – Cereals, pulses and derived products; 67.080 – Fruits. Vegetables; and 67.100 – Milk and milk products. For a detailed description of the list of the ICS fields, please refer to https://www.iso.org/publication/PUB100033.html.

[6]For a product group at the HS 2-digit level (e.g., meat), all HS 4-digit products within that HS 2-digit product group have the same standard number that corresponds to that HS 2-digit product.

[7]We finally deleted 12,931 samples representing 6.9% of the initial total sample.

TABLE 1 Descriptive statistics.

Variable	Mean	Std. dev.	Min	Max	Obs.
$\Delta quality_{fkct}$	0.087	0.671	−4.944	5.327	25,365
std_{kt}	29.133	19.112	4	147	174,353
std_i_{kt}	4.581	5.209	0	27	174,353
std_d_{kt}	24.551	16.155	3	131	174,353
DF_{fkct}	0.116	0.122	0	1	174,353
EM_{fkt} (Extensive margin)	2.356	3.108	1	55	74,017
IM_{fkct} (Intensive margin)	295921.2	1,487,985	0	981,000,000	187,284
EX_{fkct} (Exit)	0.418	0.493	0	1	187,284
Unit value/Price (USD)	3.711	22.377	0.008	6745.219	174,353
Trade value (USD)	934,466	3,683,887	56.2468	393,000,000	174,353
tar_{kct} (applied in %)	14.234	44.867	0	835.9	174,353

We finally obtain data on 16,954 Chinese firms exporting 43 products at the HS 4-digit level to 199[8] economies (see Table S3 of Appendix S1) from 2000 to 2015. The export value of the samples accounts for 44.51% of China's agri-food export value. Therefore, the seven product categories we have selected are well represented. Table 1 summarises descriptive statistics of the main variables. As a preliminary exploratory analysis, we plot the kernel density estimates of the overall quality estimates for the first and last year of sample period, as well as the kernel density estimates of the quality estimates for firms across different sizes. The results presented in panel (a) of Figure 2 indicate that the quality distribution curves for both 2000 and 2015 are left-skewed distributions, which reveals that the overall quality of Chinese exported agri-foods is still at a low level. It is worth noting, however, that the quality distribution curve in 2015 tends to skew to the right compared with the distribution curve in 2000, which to some extent implies that the average quality has improved over the study period. In addition, the distribution in panel (b) of Figure 2 shows that product quality varies amongst firms across different sizes, and the larger the size of the firm the higher its estimated quality. Figure 3 presents the scatter plot of total standards, national standards and international standards with export product quality upgrading at the firm-product-year-destination level. It can be seen from the figures that there is a positive correlation between standards, whether international or national, and quality upgrading. However, more in-depth empirical tests are required to determine whether the conclusion can be supported by the data and what the specific effects are.

5 | RESULTS AND DISCUSSION

5.1 | Baseline results

The estimation results for Equation (1) are shown in Table 2, where Columns (1) and (2) present the impact of total standards and international standards on the firm-level product quality upgrading, respectively, whilst Column (3) examines the difference between the

[8]Destination-product elasticity of substitution data from Broda et al. (2006) include only 72 economies (excluding China), but our sample retains 199 export destinations to maintain the integrity of the sample. For export destinations for which product elasticity data are not available, we use elasticities of those economies with similar mean values of GDP per capita over the sample period as an approximate proxy. For example, the elasticity data for Singapore are not included in Broda and Weinstein (2006), whilst the mean value of Japan's GDP per capita over the sample period (US$39254) is the closest to Singapore's (US$39250) among the 72 economies, so we replace Singapore's elasticity with Japan's. Furthermore, we also limited the sample to 72 export destinations and re-estimated the baseline equation, the results of which are in line with the baseline results (see Table S4 of Appendix S1 for details).

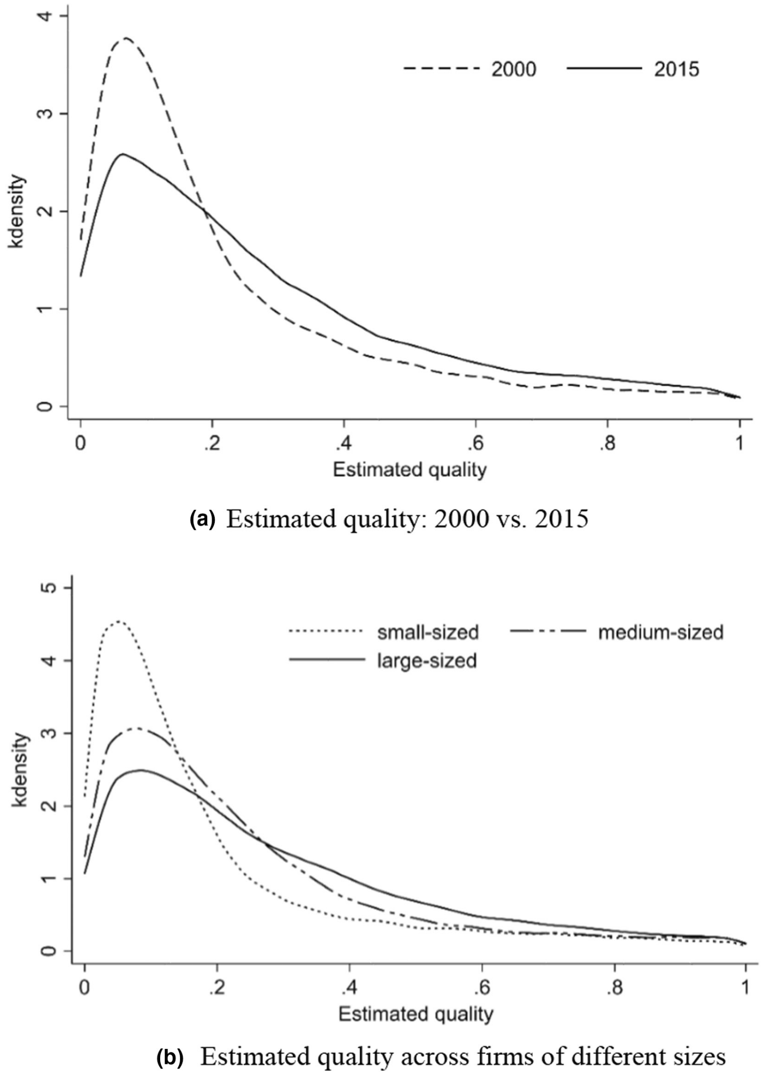
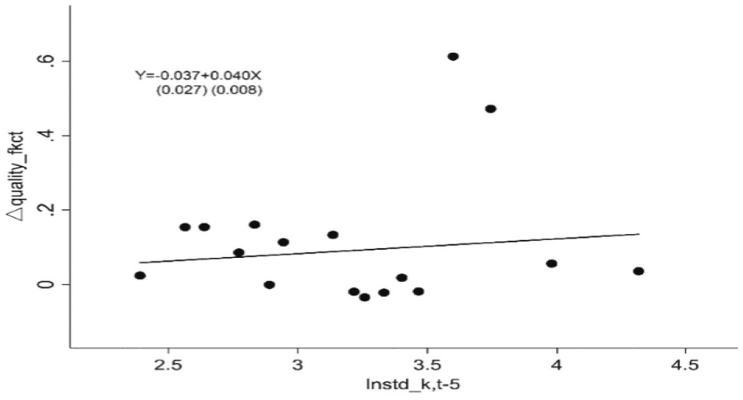


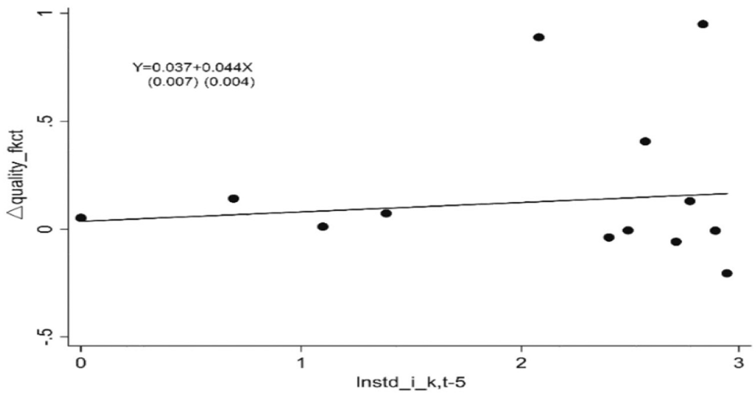
FIGURE 2 Distribution of estimated quality. *Note*: Chinese exporters are classified into three categories on average: Small-sized, medium-sized and large-sized, based on their average annual export value over the sample period, regardless of export product and market destination. The estimated quality is normalised so that it allows various comparisons across years and products.

impact of national and international standards on the quality upgrading. Considering that recent literature also uses the gravity equation that tests the standard–quality relationship, Column (4) shows the results of the gravity-like model estimation related to Equation (2). Furthermore, Columns (1)–(4) involve fixed effects of firm-year, destination-year and product, whereas Column (5) specifies an even more stringent case including firm-product-year fixed effects and destination-product-year fixed effects, which is a further test of the robustness to model specification.

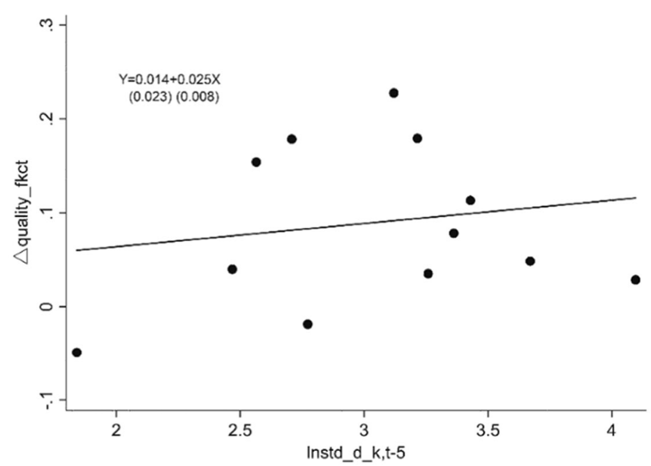
Focussing on Column (1), the coefficient of the explanatory variable standards is significantly positive, revealing that in aggregate terms, the work that China has done on agri-food product standards has been effective, resulting in quality upgrading. The interaction term of standards and quality frontier ($DF_{fkc,t-5} * lnstd_{k,t-5}$) is significantly negative, showing that a 10 per cent increase in the total number of standards drives an increase in



(a) Total standards ($lnstd_{k,t-5}$)



(b) International standards ($lnstd\_i_{k,t-5}$)



(c) National standards ($lnstd\_d_{k,t-5}$)

FIGURE 3 The relationship between standards and the quality of exported products. *Note*: All three plots are drawn using the binscatter command in Stata software to visualise the relationship between the explained and explanatory variables and to avoid the clutter caused by too large a sample size. The scatter is divided into different bins.

the level of quality upgrading of 3.91 per cent for firm-level products far from the quality frontier and a 0.52 per cent decrease in those close to the quality frontier. This means that firms far from the quality frontier are better positioned to achieve product quality upgrading with increased standards. The possible explanation comes from the fact that when standards are raised, firms that do not meet standards exit, which reduces market competition between firms. Firms with higher quality products that comply with more standards, close to the quality frontier ($DF_{fkc,t-5}$ tends to be 1), have relatively stable markets and prices as well as less export pressure, and thus lack the incentive to innovate to further achieve quality upgrading. However, standards are the minimum requirements for firms' production practices and therefore tend to bind firms far from the quality frontier. These firms choose quality upgrading to comply with the requirements of more standards to survive in the market.[9]

Column (3) shows that the positive relationship between the count of international harmonised standards and firm-level product quality upgrading is strongly significant, whilst the quality upgrading effect of national standards is just significant at the 10% level, indicating that the former might be more effective on quality than the latter. A possible interpretation is the fact that international standards, which are coordinated across countries through international bodies such as Codex Alimentarius, are able to protect the basic level of consumer health and are more likely to be accepted by importing destinations. However, national standards are mainly product standards set according to domestic reality, and compliance with national standards by exporting companies will increase fixed costs without necessarily guaranteeing acceptance for their products by the import destination. Even more importantly, the marginal effect of international standards on quality upgrading is nonmonotonic; that is, firm-level products far from the quality frontier are more likely to upgrade quality in response to an increase in international standards, whilst the opposite holds for products close to the frontier. Moreover, there is no significant relationship between tariffs and quality upgrading, which is inconsistent with the findings of Olper et al. (2014). A possible reason behind these findings is that China's average applied tariffs began to dip significantly in 1995, which is earlier than our sample period. As mentioned in Han et al. (2012), China committed to applying for WTO membership in 1995 and implemented tariff reductions and other trade liberalisation measures to gain credibility amongst its negotiating partners. It needs to be noted that when controlling for tariffs, the effect of standards on quality upgrading remains unaffected. In addition, the negative coefficient of the quality frontier ($DF_{fkc,t-5}$) indicates that China's agri-food producers tend to converge in export quality within the same export destination. This outcome implies that the further away from the quality frontier a firm is, the more room there is for quality upgrading to products, whilst closer to the quality frontier, the existence of quality bottlenecks limits the magnitude of upgrading. The conclusion is consistent with the fact that China's agri-food firm exports are deficient in medium- and high-end products.

Columns (2) and (4) present the estimated results controlling only for international standards and the results using the gravity-like equation, respectively. There is no significant change in the coefficients of key variables of interest, indicating that the estimation specification is robust. Column (5) presents the results from a more stringent model controlling for firm-product-year and destination-product-year fixed effects, which are in line with the baseline results. Since the standards variables of interest are perfectly collinear

[9]In addition, the reputation of Chinese agri-food product quality is low, as Schott (2008) finds that the United States consumers are willing to pay significantly less for Chinese exports than they are willing to pay for the same products exported from OECD. Country reputations determine the quality that buyers expect before they learn any information specific to a product. A damaged national reputation is a barrier to entry for export firms that develop more expensive high-quality products (Cagé & Rouzet, 2015). To some extent, this may also explain why Chinese agri-food firms close to the quality frontier are reluctant to upgrade quality.

TABLE 2 Baseline results.

Variables	(1)	(2)	(3)	(4)	(5)
$lnstd_{k,t-5}$	0.391***				
	(0.110)				
$DF_{fkc,t-5} * lnstd_{k,t-5}$	−0.443**				
	(0.191)				
$lnstd\_i_{k,t-5}$		0.242***	0.204***	0.048*	
		(0.052)	(0.054)	(0.027)	
$lnstd\_d_{k,t-5}$			0.169*	0.010	
			(0.087)	(0.033)	
$DF_{fkc,t-5} * lnstd\_i_{k,t-5}$		−0.643***	−0.821***		−0.983***
		(0.098)	(0.096)		(0.098)
$DF_{fkc,t-5} * lnstd\_d_{k,t-5}$			0.690***		0.373*
			(0.141)		(0.214)
$DF_{fkc,t-5}$	−0.874	−1.408***	−3.344***		−2.316***
	(0.597)	(0.117)	(0.428)		(0.664)
$lntar_{kc,t-5}$	0.013	0.012	0.010	0.018	0.003
	(0.015)	(0.016)	(0.016)	(0.015)	(0.018)
Constant	−0.741**	0.163**	−0.273	−0.017	0.554***
	(0.342)	(0.069)	(0.269)	(0.098)	(0.036)
Product	YES	YES	YES	YES	NO
Firm-Year	YES	YES	YES	YES	NO
Destination-Year	YES	YES	YES	YES	NO
Firm-Product-Year	NO	NO	NO	NO	YES
Destination-Product-Year	NO	NO	NO	NO	YES
R^2	0.737	0.741	0.742	0.683	0.671
Observations	25,365	25,365	25,365	25,365	23,027

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Numbers in parentheses are robust standard errors, which cluster at the firm level. To deal with the high-dimensional fixed effects in our model specifications, we use the user-written commands reghdfe in Stata by Correia (2016) in estimating models (1)–(5). Models (1)–(4) include destination-year, firm-year and product fixed effects. Model (5) includes firm-product-year and destination-product-year fixed effects. The unit of observation of all models is firm-destination-product-year.

with the two high-dimensional fixed effects, Column (5) does not report the coefficients of the standards. This implies that using the estimates from this more rigorous model, we cannot examine the nonmonotonic quality upgrading choices of Chinese firms at different frontier distances in response to the increased standards. Therefore, in the analysis that follows, we focus on model results that control only for firm-year, destination-year and product fixed effects.

5.2 | Robustness checks

To further verify the robustness of our main results, we test whether the results hold when using alternative computation methods of product quality, different treatments for samples and different definitions of quality upgrading.

First, product quality is estimated using an alternative method to show the robustness of the baseline results. One of the most widely used proxy variables in the literature is unit value from trade data, which indicates that changes in the unit value of exports can well explain variation in the quality of export products (Hummels & Klenow, 2005). Thus, except for the main results reported, we use unit value (also known as Price) as a proxy variable for product quality; that is, unit price change between periods *t* and *t*-5 represents the dependent variable ($\Delta quality_{fkct}$) in Equation (1). And the estimates are shown in Columns (1)–(2) of Table 3. However, the results of the variables of interest are lower in magnitude and not significant, showing that unit value is not a valid indicator of the quality of China's agri-food products and thus does not capture this quality change.

For a further robustness check, we then focus on a subsample limited to a balanced panel of firms exporting continuously from 2000 to 2015 to avoid potential selection bias caused by the entry or exit of firms in the sample. There are 16,954 firms in the total sample of this article, but only 72 firms exported continuously from 2000 to 2015.[10] We retain only those firms that exported continuously, which account for 25.4% of the total exports in the sample. The regression results corresponding to subsample are reported in Columns (3) and (4) of Table 3. The signs of the estimated coefficients of Columns (3) and (4) are consistent with the findings revealed in Table 2. The results further support the findings on international standards, even if the magnitudes of quality upgrading effects have some variation compared with those of the baseline estimate.

Finally, quality upgrading is defined as the quality change between periods t and t-5 in our baseline equation. To avoid biased results caused by improper selection of periods, we define quality upgrading as the quality change between periods t and t-3. Accordingly, all explanatory variables are lagged by 3 years. The estimation results in Columns (5) to (6) of Table 3 are consistent with the baseline regression. Thus, it is reasonable to choose five periods to define the dependent variable as there is no significant change in the results of the variables of interest; that is, international standards exert a positive impact on quality upgrading.

5.3 | Heterogeneity test

We examine whether standards have heterogeneous effects on quality upgrading across subsamples, which are split based on the degree of international standards adoption, firm scale and ownership structure, as shown in Table 4.

5.3.1 | Heterogeneity in the degree of international standards adoption

The degree of harmonisation of Chinese standards to international standards has been divided into IDT standards and MOD standards as stated above, with a significant difference between the two approaches to adoption. IDT standards imply no changes to the technical content of international standards except for some editorial changes; MOD standards mean that some key technical differences are allowed to exist between national standards and international standards, which need to be noted and explained. Column (1) of Table 4 reports that the effects of IDT and MOD standards on firm-level product quality upgrading

[10]Because our regression equations are estimated at the firm-product-destination-year level, here, we define continuous exporters as firms that export a specific product (at HS 4-digit level) to a specific export destination without interruption during the period 2000–2015.

TABLE 3 Robustness checks.

Variables	Unit value (1)	Unit value (2)	Continuous exporters (3)	Continuous exporters (4)	Lag3 (5)	Lag3 (6)
$lnstd_{k,t-5}$	−0.009*		0.406***		0.236***	
	(0.005)		(0.142)		(0.067)	
$DF_{fkc,t-5} * lnstd_{k,t-5}$	0.051*		−0.053		−0.230	
	(0.031)		(0.294)		(0.147)	
$lnstd\_i_{k,t-5}$		0.0003		0.189**		0.136***
		(0.002)		(0.076)		(0.030)
$lnstd\_d_{k,t-5}$		−0.018		0.108*		0.110**
		(0.012)		(0.118)		(0.052)
$DF_{fkc,t-5} * lnstd\_i_{k,t-5}$		0.049***		−0.589***		−0.765***
		(0.015)		(0.177)		(0.081)
$DF_{fkc,t-5} * lnstd\_d_{k,t-5}$		−0.002		0.679***		0.783***
		(0.025)		(0.209)		(0.115)
$DF_{fkc,t-5}$	−0.260***	−0.146**	−1.945**	−3.389***	−1.448***	−3.482***
	(0.097)	(0.074)	(0.934)	(0.647)	(0.469)	(0.354)
$lntar_{kc,t-5}$	−0.001	−0.001	0.007	0.003	−0.001	−0.004
	(0.001)	(0.001)	(0.024)	(0.025)	(0.009)	(0.009)
Constant	0.036**	0.059*	−0.806*	−0.390	−0.341	−0.108
	(0.016)	(0.033)	(0.454)	(0.365)	(0.210)	(0.170)
R^2	0.665	0.668	0.667	0.672	0.700	0.706
Observations	25,365	25,365	7458	7458	44,367	44,367

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Numbers in parentheses are robust standard errors, which cluster at the firm level. To deal with the high-dimensional fixed effects in our model specifications, we use the user-written commands reghdfe by Correia (2016) in estimating models (1)–(6). All models include destination-year, firm-year and product fixed effects. The unit of observation of all models is firm-destination-product-year.

TABLE 4 Heterogeneous effects.

	International standard category	Firm size			Firm ownership		
		Small-sized	Medium-sized	Large-sized	State-owned	Foreign-invested	Private
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
$lnstd\_i_{k,t-5}$		0.284***	0.328***	0.151**	0.137***	0.263*	0.203***
		(0.082)	(0.099)	(0.059)	(0.045)	(0.138)	(0.033)
$lnstd\_d_{k,t-5}$	0.015	0.381	0.166	0.204*	0.047	−0.117***	0.081
	(0.088)	(0.253)	(0.232)	(0.105)	(0.042)	(0.035)	(0.049)
$lnstd\_i_{k,t-5}\_IDT$	0.236**						
	(0.092)						
$lnstd\_i_{k,t-5}\_MOD$	0.290***						
	(0.095)						
$DF_{fkc,t-5} * lnstd\_i_{k,t-5}$		−0.976***	−0.887***	−0.815***	−0.340***	−0.208	−0.690***
		(0.277)	(0.187)	(0.111)	(0.128)	(0.178)	(0.127)
$DF_{fkc,t-5} * lnstd\_d_{k,t-5}$	0.741***	1.723***	0.579*	0.582***	0.205	0.140	−0.153
	(0.197)	(0.479)	(0.326)	(0.165)	(0.187)	(0.184)	(0.199)
$DF_{fkc,t-5} * lnstd\_i_{k,t-5}\_IDT$	0.053						
	(0.237)						
$DF_{fkc,t-5} * lnstd\_i_{k,t-5}\_MOD$	−1.027***						
	(0.150)						
$DF_{fkc,t-5}$	−4.180***	−6.680***	−3.209***	−2.919***	−1.073*	−1.169*	−0.032
	(0.534)	(1.403)	(0.989)	(0.507)	(0.624)	(0.598)	(0.638)
$lntar_{kc,t-5}$	0.013	−0.007	0.012	0.016	0.031	−0.020	0.020
	(0.016)	(0.007)	(0.021)	(0.020)	(0.024)	(0.018)	(0.037)
Constant	0.268	−1.039	−0.379	−0.155	−0.106	−0.331*	−0.022
	(0.253)	(0.747)	(0.732)	(0.324)	(0.140)	(0.199)	(0.161)
R^2	0.743	0.966	0.869	0.643	0.707	0.840	0.819
Observations	25,365	5522	8639	11,204	5406	9991	8447

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Numbers in parentheses are robust standard errors, which cluster at the firm level. To deal with the high-dimensional fixed effects in our model specifications, we use the user-written commands reghdfe by Correia (2016) in estimating models (1)–(7). All models include destination-year, firm-year and product fixed effects. The unit of observation of all models is firm-destination-product-year.

are positive and statistically significant at the 5% level or lower. The upgrading effect of MOD standards, which are modified versions of international standards, is 0.054% higher than that of IDT standards. It reveals that to a limited extent, the degree of international standards adoption can be better integrated with China's national conditions and is more conducive to promoting quality upgrading. In addition, a positive coefficient on the linear MOD standards and a negative coefficient on the interaction term imply a nonmonotonic relationship; that is, the current non-linear impact of international standards on quality upgrading is mainly driven by the MOD standards.

5.3.2 | Heterogeneity within firm size

It has been suggested that there is heterogeneity in the impact of standards on firm-level export quality for developing countries across exporters of different sizes (Curzi et al., 2020). Thus, to determine potential heterogeneous effects across firm sizes, we divide China's exporters into three categories on average: small-sized, medium-sized and large-sized based on their average annual export value over the sample period, regardless of export product and market destination. Columns (2)–(4) in Table 4 summarise the regression results for the various samples.[11] The results clearly show that the quality upgrading of agri-food exports in the case of small-sized and medium-sized firms is positively affected by international standards at the 1% significance level, whilst this marginal effect in the case of large-sized firms is smaller, only passing the 5% significance level. This outcome may be because larger exporters are already operating at a higher level of product quality due to complete standard specifications and higher requirements for product quality. Conversely, smaller exporters at a competitive disadvantage merely export lower-priced, poorer quality products. Then, these firms have a significant export incentive in the face of increasing standards, which is to react more quickly to adapt their quality to the new requirements than larger firms and prevent exit from the market. We also find that national standards are insignificantly associated with quality upgrading conditional on different firm sizes.

5.3.3 | Heterogeneity in ownership structure

Agri-food firms with different ownership structures vary widely in terms of organisational structure, degree of constraints and access to financial support, and thus their behaviours in the face of standard constraints may vary. We test whether standards exert heterogeneous effects across firms with different ownership structures. According to each firm's information, the agri-food producers are grouped into three categories: state-owned collective firms, foreign-invested firms and private firms, and the specific results are presented in Columns (5)–(7) in Table 4. The estimation results are largely in line with the expectations above. Given international standards, the resultant coefficients of all three types of agri-food firms passed the 10% significance test with a positive sign, where the quality upgrading effect is the most prominent for foreign-invested firms and the smallest for state-owned ones. This finding is in line with the reality that the main source of capital for foreign-invested firms is foreign investment, some of which export directly to the investing countries. They are willing to upgrade product quality to maintain exports when confronted

[11]To make the key variables comparable across the samples, we use the suest command to test for differences in the estimation coefficients. The results show significant variation in the coefficients of variables of interest, passing the 10% level of significance. These additional results are available from the authors upon request.

with rising international standards. By contrast, state-owned firms, which account for a relatively smaller share of exports, have a significantly weaker awareness and motivation for R&D and innovation than non-state-owned firms, and thus present a poorer performance in quality upgrading effect. Furthermore, the insignificant coefficient of the interaction ($DF_{fkc,t-5} * lnstd\_i_{k,t-5}$) in the case of foreign-invested firms shows that products close to or far from the quality frontier both show a quality-enhancing effect.

5.4 | Extensive and intensive margins

The impact of standards on trade could be analysed as a complement to the examination of that on quality upgrading. We study the trade effect of standards on trade margins, using the following equation:

$$\begin{aligned} Y = \alpha + \beta_1 std\_i_{kt} + \beta_2 std\_d_{kt} + \beta_3 DF_{fkct} + \beta_4 DF_{fkct} * std\_i_{kt} + \beta_5 DF_{fkct} * std\_d_{kt} \\ + \beta_6 tar_{kct} + \delta_{ft} + \delta_k + \delta_{ct} + \varepsilon_{fckt} \end{aligned} \tag{6}$$

where the subscripts f, k, c and t represent the firm, product category, export destination and year, respectively. We estimate this equation for three different dependent variables: (1) EM_{fkt} is a variable for the extensive margin that is the logarithm of the total number of destinations to which firm f exported product k in year t; (2) IM_{fkct} is the intensive margin that is the logarithm of the trade value of firm f that exported product k to destination c in year t; and (3) EX_{fkct} is a dummy variable accounting for the exit of firms from a product-destination pair market. δ_{ft}, δ_{ct} and δ_k are fixed effect terms for the firm-year, destination-year and product. These fixed effects control for destination and time-varying effects within firms (e.g. distance, productivity, income and population.) and product variety differences, which is similar to Equation (1).

The estimation strategy of gravity models in international trade needs to address several empirical challenges (Ehrich & Mangelsdorf, 2018). The first challenge is the existence of multilateral resistance, which refers to the theoretically appropriate average trade barrier. The omission of this term causes estimation bias (Anderson & Van Wincoop, 2003). In Equation (6), we use destination-year fixed effects (α_{ct}) to account for multilateral resistance in line with Xiong and Beghin (2012) as occurring frequently. Second, we also use the Poisson-pseudo-maximum likelihood (PPML) estimator to test the standards on trade flows to avoid the effect of zero trade value in explained variables (Shingal et al., 2020). Third, to control for heteroskedasticity, we compute robust standard errors clustered at the firm level to address the potential correlation of error terms within each firm across different products over time (Fan et al., 2015).

Table 5 reports the estimated effects of the standards on trade flows, and Columns (1) and (3) are the results of OLS regression, and Columns (2) and (4) are in the PPML estimator. The signs of coefficients using PPML, which we are interested in, are consistent with those from the OLS model, but the significance of the coefficients is increased by controlling for sample selection bias. The estimation results show that both extensive and intensive margins increase with international standards. It can be argued that international standards can promote quality upgrading, helping China's exporters explore new export markets and increase their market share in export destinations. Moreover, the results hold when considering whether exporters are close to or far from the quality frontier. The coefficient of the interaction term shows that firms close to or far from the frontier present trade enhancing effects. Moving to Column (5), we find that the impact of international standards on the exit probability is not significant. In addition, when looking at the results in the case of national standards, national standards lead to a significant increase in the probability of firms ceasing to export a given product to a given destination. The results strongly corroborate

TABLE 5 Estimated effects on trade margins.

	EM_{fkt}		IM_{fkct}		EX_{fkct}
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
std_i_{kt}	0.007**	0.009**	0.007	0.039***	0.003
	(0.003)	(0.004)	(0.005)	(0.014)	(0.005)
std_d_{kt}	−0.013*	−0.002	−0.015***	−0.047***	0.007***
	(0.007)	(0.003)	(0.004)	(0.006)	(0.002)
$DF_{fkct} * std\_i_{kt}$	−0.018	−0.015	−0.009	0.097***	0.079***
	(0.016)	(0.024)	(0.023)	(0.026)	(0.019)
$DF_{fkct} * std\_d_{kt}$	0.004	0.006	0.010	−0.063***	−0.037***
	(0.004)	(0.005)	(0.008)	(0.013)	(0.008)
DF_{fkct}	0.359***	0.445*	6.848***	7.159***	−3.398***
	(0.138)	(0.238)	(0.234)	(0.377)	(0.187)
tar_{kct}	0.001***	0.0003***	0.0002	0.002***	0.018*
	(0.0003)	(0.0001)	(0.0003)	(0.001)	(0.011)
Constant	0.461***	1.427***	10.259***	14.708***	0.341
	(0.028)	(0.059)	(0.096)	(0.215)	(0.442)
Product	YES	YES	YES	YES	YES
Firm-Year	YES	YES	YES	YES	YES
Destination-Year	YES	YES	YES	YES	YES
R^2/ Pseudo R^2	0.961	0.503	0.681	0.842	0.064
Observations	74,017	74,017	174,353	187,284	187,284

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Numbers in parentheses are robust standard errors, which cluster at the firm level. The independent variables in Columns (1)–(4) are log-specified. To deal with the high-dimensional fixed effects in our model specifications, we use the user-written commands reghdfe and ppmlhdfe of Correia (2016) in Stata. Columns (1) and (3) are estimated using OLS, Columns (2) and (4) are estimated using PPML, and Column (5) is estimated using a linear probability model (LPM) referring to Curzi et al. (2020). All models include destination-year, firm-year and product fixed effects. The unit of observation of Column (1)–(2) is firm-product-year, and that of Column (3)–(5) is firm-destination-product-year.

the findings on the extensive and intensive margins, which occur mainly because national standards examined in the previous section do not have the effect of promoting quality upgrading in products at the firm level.

6 | CONCLUSIONS

China is actively involved in the internationalisation of standards and is committed to aligning its standards with international standards. This paper uses matched China agri-food product standards data and firm-product customs data over the period from 2000 to 2015 to empirically test the impact of China's agri-food product standards on firm-level product quality upgrading and performs focal testing of how the internationalisation of standards affects the quality upgrading and trade flows.

Our empirical results indicate that standards have significant promoting effects on firm-level product quality upgrading, especially in the case of international standards. The quality upgrading effect of international standards is nonmonotonic, and a firm-level product far from the quality frontier is more likely to quality upgrading in response to an increase in international standards. These conclusions hold for different sample handling methods and different definitions of quality upgrading. Second, our results report the marginal effect of standards under heterogeneity testing. We find that MOD standards, which are modified versions of international standards and better integrated with China's national conditions, have increasing stronger quality upgrading effects than IDT standards. The heterogeneous effects further prove that the positive correlation between international standards and quality upgrading is even stronger for smaller firms and foreign-invested firms. Finally, examining the standards–trade relationship at binary margins we find that international standards exert an increase in the intensive margin and extensive margin.

The results emerging from this paper have some relevant policy implications. First, the process of harmonising Chinese standards to international measures has yielded positive outcomes, showing the effective promotion of quality upgrading in China's agri-food exports. This quality upgrading effect of international standards is more beneficial to expanding the scope of export destinations and increasing market share than that of national standards. Therefore, Chinese authorities need to give priority to continuing harmonisation with international measures. Second, the effect of standards on quality upgrading across different degrees of harmonisation with international standards is quite heterogeneous, especially MOD standards that consider the actual situation in China, which show a larger effect on quality upgrading. Therefore, it is necessary for China to actively participate in international standards-setting organisations such as the Codex Alimentarius Commission and the International Plant Protection Convention. Participation in international organisations may allow Chinese stakeholders not only to be ‘standard takers’ but also to be able to incorporate specific domestic preferences into international norms and may facilitate adoption in the agri-food sector. Third, our estimation results show limited quality-enhancing effects for firms close to the frontier distance, so other policy incentives may be needed for such firms.

Clearly, all the preceding findings are the results of a study focussed on China. As such, whilst these results are robust for China, we cannot generalise them to all countries or the complex role played by the standards implemented by the exporting countries in global export activity. However, by examining China's agri-food firm data, our analysis assesses the effect of international harmonised standards on the quality of its exporting products in developing countries. In addition, to the best of our knowledge, this paper is one of few studies that discuss the standards–quality relationship and standards–trade relationship simultaneously. From these perspectives, our analysis offers a better understanding of how international standards affect trade volume by upgrading export quality. The study undoubtedly possesses limitations. One limitation lies in standard measurements; that is, the study does not measure the stringency of standards. Thus, our estimations capture only the relationship between the count of standards and the quality upgrading of China's agri-food exporting firms.

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DATA AVAILABILITY STATEMENT

The data for trade and standards are available in the following public repository: http://43.248.49.97/ and https://std.samr.gov.cn/gb/search/gbAdvancedSearch, respectively. The merged panel data set and codes that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1

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