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How can trade partners be chosen when facing food scandals? China's milk scandal as a natural experiment

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Abstract

Using China's milk scandal as a natural experiment, this paper explores whether the countries of origin and export destinations have the same responses to the original country's food scandal. Our difference-in-difference estimation shows that the outbreak of China's milk scandal had asymmetric impacts on China's total imports (increased by 23.4%) and exports (sharply dropped by 65.8%). The results further show that China's milk scandal contributed to import increases from European and Oceanian countries. Moreover, China's milk scandal worsened exports, mainly those going to neighbouring Asian regions but increased exports to Oceania. A product quality index is constructed to explain this finding. Intuitively, consumers' perceived quality of Chinese products declined, and they tended to consume products from other countries. The lower the product quality was with those in China, the lower the perceived quality and safety, thereby affecting demand. During the scandal, Chinese consumers tended to buy high-quality dairy products from Europe and Oceania rather than the perceived unreliable dairy products produced by China or neighbouring countries. We conclude that product quality plays a key role in imports and exports when facing food scandals.

KEYWORDS

China's milk scandal, difference-in-difference, food fraud, heterogeneity effect

JEL CLASSIFICATION

Q17, Q18, F14

Wenshou Yan, Yan Cai and Xuan Guo contributed equally.

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1 | INTRODUCTION

In recent years, food fraud has exacted a large global health toll (Hoffmann et al., 2019; Li et al., 2022), which has come under increased scrutiny as a potential food safety and public health concern (Handford et al., 2016; Soon & Liu, 2020; Spink & Moyer, 2011; Stevens et al., 2018).¹ The literature has documented that food scandals not only decrease a firm's market share (Burton & Young, 1996) and its performance (Heerde et al., 2007), but also negatively impact the reputation of the enterprise (Breitenbach et al., 2018), leading to changes in consumers' expenditure distribution on those products (Böcker & Hanf, 2000; Gao et al., 2020; Hoffmann et al., 2019). However, the effects of food scandals on international trade and international sourcing have received little attention. How do food scandals affect imports and exports? Will the countries of origin (import partners) and export destinations (export partners) have the same responses to food scandal in a country? In this study, we aim to investigate these important yet unsettled research questions using China's 2008 milk scandal as a natural experiment.

The melamine-contaminated infant formula in 2008 brought China's milk scandal into the spotlight (named 'China's milk scandal' throughout the rest of this paper).² We focus on the milk industry and China's milk scandal in 2008 for several reasons. Dairy products are an important source of protein and calcium in the human diet, which also holds true for China (Yang et al., 2020). During the past three decades, the world's milk production has increased by more than 60%, from 530 million tonnes in 1988 to 852 million tonnes in 2019.³ As a result of the milk scandal, the safety and authenticity of milk (and its products) have become an area of growing focus and concern (Montgomery et al., 2020; Zhang et al., 2021). World dairy exports were forecasted to reach 78 million tonnes (milk equivalent) in 2020, up 1.5% year over year, a pace of expansion almost equal to the average growth rate of the preceding 5 years. This increase is attributed primarily to the persistently high global import demand sustained by China, which reflects its increased economic activities (FAO, 2020). China's milk scandal brought food fraud into the spotlight (Yang et al., 2020). This incident had grave consequences for Chinese citizens and the Chinese milk industry. By December 2008, four infants had died, 51,900 children were hospitalised and 700 tonnes of milk powder had been recalled nationwide (Bai et al., 2022). Making fraud vulnerability assessments is the first step towards food fraud prevention and mitigation. China's milk scandal in 2008 offers an ideal setting for examining this issue. As a sudden event, there is no expected effect when we identify the causal effect of China's milk scandal on international trade and sourcing. In addition, because of the attribution of agricultural products, the plausible exogenous shock varies across sectors. We can explore this across-sector variation to identify its impact on international trade and sourcing.

We start our analysis by introducing the background of China's milk scandal in 2008 and by then documenting stylised facts. Drawing evidence from a large panel of data from the United Nations Trade Commodity Statistics Database (UN Comtrade) between 2002 and 2014, we show that China's milk imports began to rise, and the growth rate gradually increased. China's

¹Food fraud has the potential to become a food safety issue if there is the potential for harm to consumers (IFST, 2021). When food fraud or a food safety issue is exposed by the media, it becomes a food scandal. In recent years, an increasing number of food scandals have been exposed, such as the bovine spongiform encephalopathy (BSE) scandal in Britain, the dioxin scandal of German animal feed, the sale of expired and adulterated meat in Brazil, the dicyandiamide (DCD) scandal of New Zealand dairy products and the numerous salmonella incidents in the United States.

²In 2008, milk was intentionally diluted and adulterated with melamine to increase the apparent protein content because of the increased nitrogen content from melamine. In powdered infant formula made from the adulterated milk, melamine levels as high as 4400 mg/kg were recorded. What started as a food fraud incident became a food safety issue when the infant milk formula was linked to urinary tract ailments (crystals and stones in the urine leading to kidney stones) resulting in the hospitalisation of nearly 52,000 infants and six deaths (IFST, 2021).

³Dairy production and products: Production (fao.org).

dairy exports dropped significantly after the China's milk scandal, and the export value returned to its prescandal level until the end of 2014.

To rationalise these facts and identify the causal effects of China's milk scandal on international trade, we have selected two types of goods with Harmonisation System (HS) codes 0401 and 0405 as the treatment group and control group, respectively. Among these, 0401 represents milk and cream, which were directly related to the scandal, while 0405 denotes butter and other fats and oils derived from milk, which were less relevant to the scandal (Luong et al., 2018). After conducting the policy expectation effect test and parallel test, our difference-in-difference (DID) estimations show that the outbreak of China's milk scandal contributed to larger imports, increased by 23.4%, damaging the total exports of dairy products from China, which dramatically dropped by 65.8%.

We then explored how China's milk scandal had heterogeneity effects on countries of origin (import effect) and export destinations (export effect). By dividing all of China's trade partner countries into six regions, we found that China's milk scandal had asymmetric effects on imports and exports. Specifically, China's milk scandal worsened exports, mainly to Asian regions. Specifically, China's milk scandal worsened exports, mainly those going to neighbouring Asian regions but increased exports to Oceania.

To explain the heterogeneous effect of China's milk scandal, we constructed a product quality index based on the model of Khandelwal, Schott and Wei (2013) (hereafter KSW model). We found that after the scandal, China's dairy products exported to Oceania increased, which is related to an improvement in product quality. The rise in imports from Oceania and Europe could also be explained by the higher quality of imported products after China's milk scandal.

Our study contributes to the literature in several ways. Firstly, our paper supplements the growing economics literature on the effects of food scandals. The literature mainly focusses on the impact of food scandals on consumer confidence (Kendall et al., 2019; Ortega et al., 2011; Soon & Liu, 2020), market share or firm reputation of scandal-related enterprises (Böcker & Hanf, 2000; Breitenbach et al., 2018) and the performance of dairy production farmers (Huang et al., 2012; Jia et al., 2012), while the effect on demand from the international market has received little attention (Dang & Xu, 2018). This study also examines the impact of food scandals on demand in domestic markets, as well as international markets, helping to fully understand the international impact of food scandals and better respond to the crisis.

Secondly, most papers on food scandals and trade have concentrated on the entire import and export industry across the globe. Some research has pointed out that the imports of scandal-related products will increase and exports decrease accordingly after a food scandal (Bai et al., 2022; Dang & Xu, 2018). In addition, after a food scandal, suppliers will have a much higher negative effect on trade than before (Schaefer et al., 2018). This paper contributes to the literature on food scandals and trade by revealing the heterogeneous effect of food scandals on consumers' demand in different countries and regions. This paper fills this research gap regarding the heterogeneous influence of food scandals in different regions.

Thirdly, this paper enriches the literature on the quality of dairy products entering and leaving a country. Quality plays an important role as a determinant of the global patterns of bilateral trade (Hallak, 2006). There is a rich body of literature on the quality of imported and exported products (Ciani, 2021; Li et al., 2020; Su et al., 2018). However, relatively few works have been devoted to the quality of food, particularly in relation to exogenous shocks and product quality. This paper finds that the quality of China's dairy exports fell sharply and the quality of imports improved in the wake of the food scandal. This paper also provides avenues for how a company, or even country, can quickly overcome the effects of a food scandal and improve the competitiveness of products.

The effects of food scandals on international trade and sourcing could be driven by several channels. Social media can amplify the negative impact of food scandals by influencing public opinion and consumer choices (Stevens et al., 2018). The media's hype and publicity of a scandal can also affect consumers' perceptions and consumption behaviour (Luong et al., 2018), thus

increasing the negative effects of the scandal and lowering consumption (Rieger et al., 2016; Verbeke & Ward, 2001). At the same time, countries and enterprises that have been criticised by the media will also be more affected by scandals (Koenig & Poncet, 2019). Food fraud and the amplification effect of the media can cause consumers to lose confidence in scandal-related products (Grolleau et al., 2020), and these consumers are often unwilling to buy these products again for a long time. In addition, because of the spillover effect emerging from an industry's collective reputation (Neeman et al., 2019), food scandals in one or several enterprises may affect other enterprises in the industry. Even if these enterprises are identified as manufacturers without food contamination, exports will also significantly drop (Bai et al., 2022). Finally, there are heterogeneous responses to food scandals. Consumers' heterogeneity in their psychology and behaviour, attention to media and consumption habits will make them react to food scandals to varying degrees (Rieger et al., 2017). We explain this heterogeneous effect as consumers being more likely to buy high-quality products that are more reliable and trustworthy.

The remainder of this paper is organised as follows: Section 2 introduces the background of China's milk scandal and the import and export of dairy products during the scandal period; Section 3 provides a summary of the data and presents the empirical strategy; Section 4 presents the empirical results and discussion; Section 5 further explores the heterogeneous effects of China's milk scandal on trade across regions; Section 6 provides a plausible explanation of the heterogeneity effect; and the final section concludes the paper.

2 | BACKGROUND

2.1 | The milk scandal in China in 2008

On 28 June 2008, 14 infants and young children in Lanzhou, China, were diagnosed with symptoms of kidney stones; the link among these 14 infants and young children is that they had consumed milk powder produced by the Sanlu Group. The incident aroused widespread concern. After this initial discovery, many similar incidents occurred in various cities. After the general administration of quality supervision, inspection and quarantine, China released a melamine test report on milk powder produced by domestic dairy manufacturers, and the incident rapidly deteriorated. It was found that 22 well-known domestic enterprises, including Yili, Mengniu and Guangming, all had varying degrees of melamine in milk powder, which triggered a shockwave in the dairy industry. Melamine is a chemical raw material that is artificially and illegally added to raw milk and milk powder to improve the product's protein value. If people take it for a long period, it will cause kidney stones and lead to kidney failure. By December 2008, 300,000 infants had urinary system abnormalities because of consuming melamine-tainted powdered milk, and six infants died.

This incident was a serious food safety accident and aroused widespread concern among consumers all over the world, as well as doubts about the quality and safety of Chinese dairy products. Because of the special status of the scandal-led Sanlu Group and the loopholes in China's dairy industry that were later exposed, the reputation of Chinese manufactured goods was severely damaged, and many countries banned the import of Chinese dairy products. The development of China's dairy industry, which had been in rapid development, stagnated, and the levels of consumer awareness and confidence that had been built up over the years disintegrated. At the same time, domestic milk powder manufacturers began to increase their purchasing share of imported raw materials, and the amount of imported milk powder surged. By 2011, China Central Television's Weekly Quality Report found that 70% of Chinese consumers were still afraid of buying domestic milk.⁴

⁴Source: https://www.sohu.com/a/111671776_387322.

The melamine scandal, which was widely covered by domestic and foreign media, is considered an unforeseen major risk event; it caused domestic and foreign consumers and distributors of import and export commodities to attach importance to the safety of dairy products in China (Yang et al., 2019). The whole dairy industry was greatly affected, and even enterprises that were not illegally adding melamine to dairy products saw a significant drop in their sales (Bai et al., 2022).

Using the 2008 dairy scandal in China as an example, this paper identifies the causal relationship between food scandals and imports and exports through a DID framework. The DID approach can help us eliminate the influence of interference factors other than the scandal on the import and export of dairy products to accurately identify the impact of the scandal. After the scandal, consumers lost confidence in the safety of Chinese dairy products. Hence, Chinese consumers met their original demand for dairy products by increasing their consumption of foreign dairy products, while foreign consumers turned to their own countries and other countries to buy dairy products. This caused an exogenous impact on the import and export of China's dairy industry, thus forming a quasi-natural experiment. Using this quasi-natural experiment, we studied the impact of China's dairy imports and exports after the milk scandal. In addition, our research divides different countries and regions in the world according to their geographical locations and economic development status. By doing this, we can better understand the differences in the degree of reflection of China's dairy scandal in different regions and countries with different economic development statuses.

2.2 | The import and export of China's dairy products

Since the implementation of China's economic opening policy, international trade has increased. Although China is not famous for exporting milk products like Australia or New Zealand, the export volume of dairy is still considerable. As the world's most populous country, China imports a large number of dairy products from abroad every year.

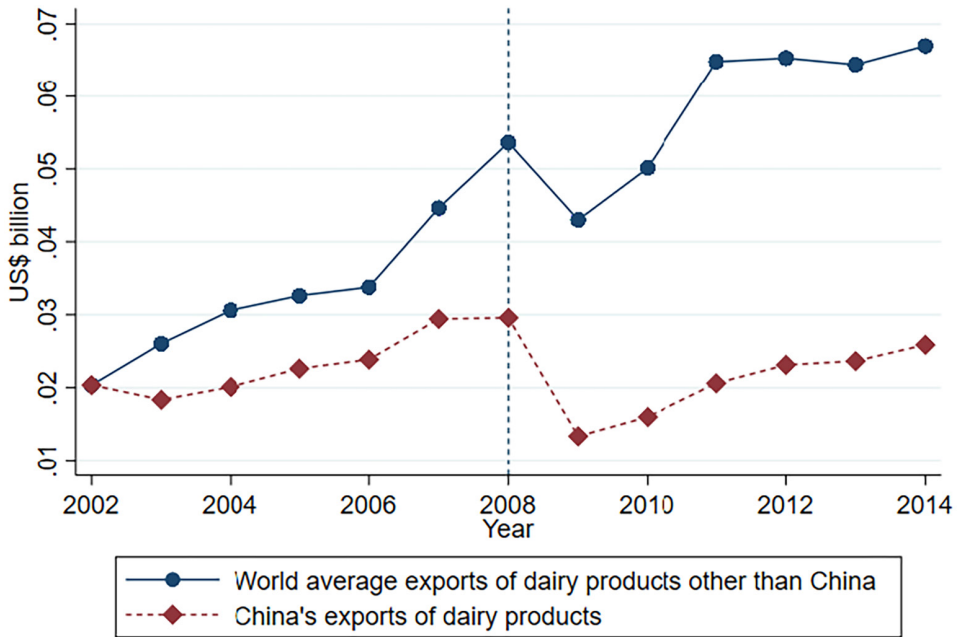
Figure 1 shows the changes in dairy products with HS code 0401 in China and the rest of the world from 2002 to 2014. From Figure 1, we can more intuitively see the growth rate of dairy products in China and the world. China's dairy product exports are far smaller than the world average level, and the gap is gradually expanding, while the growth rate of China's dairy products export is far greater than the world average level. Specifically, before 2008, China's dairy exports were about 25 million. However, after the milk scandal occurred, this situation quickly changed. China's dairy product exports rapidly dropped from 30 million in 2008 to about 12 million.

As can be seen from Figure 2, China's dairy import volume was very low from 2002 to 2007, being less than 20 million, and the speed of its growth was quite slow. However, since 2008, the increased rate of China's milk imports began to show an exponential growth trend. In 2012, China's imported dairy products reached 120 million US dollars. Chinese dairy products were also growing much faster than the world average, and the pace accelerated significantly in the wake of the milk scandal.

3 | DATA, VARIABLES AND EMPIRICAL STRATEGY

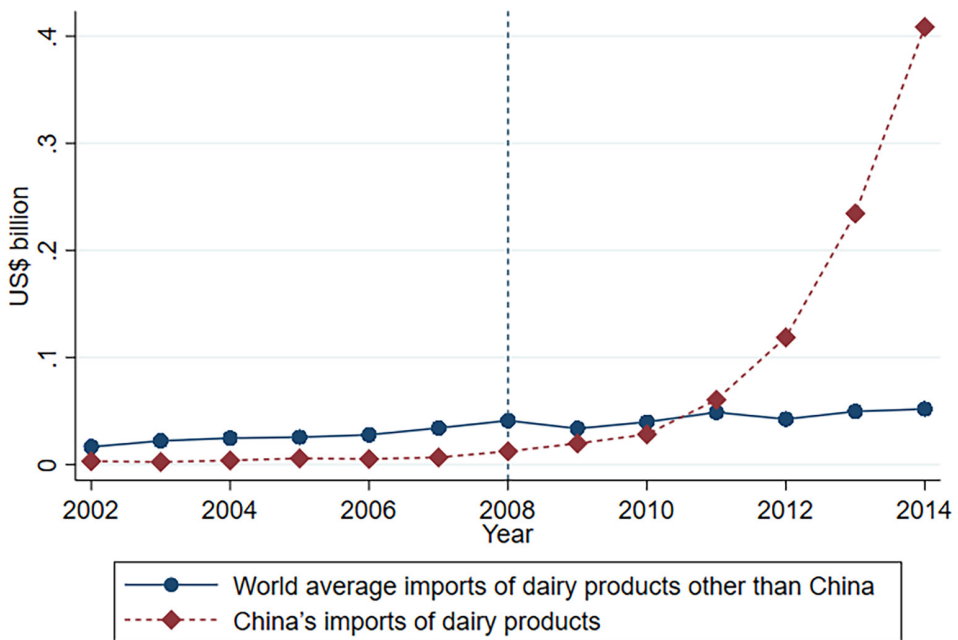
3.1 | Data source and variables

The data used for our analysis cover the years 2002–2014, 6 years before and after the dairy scandal (2008) came to light. Data with HS codes 0401 and 0405 have been selected for the import and export data of dairy products.



Source: UN Comtrade

FIGURE 1 Dairy product exports by China and the rest of the world, 2002–2014. [Colour figure can be viewed at wileyonlinelibrary.com]



Source: UN Comtrade

FIGURE 2 Dairy products imported by China and the rest of the world, 2002–2014. [Colour figure can be viewed at wileyonlinelibrary.com]

The dairy products coded as 0401 are the treatment group, including milk and cream, and the products coded as 0405 are the control group, covering butter and other fats and oils derived from milk. Because the milk scandal occurred in 2008, the period of 2002–2007 represents the before-impact group, while the period of 2009–2014 is classified as the after-impact group. We have used the logarithm of dairy product trade as the outcome variable. These data come from the United Nations Trade Commodity Statistics Database (UN Comtrade).

Table 1 shows the summary statistics for the full sample of the outcome variable and separately for by-products and impact year. We found that the logarithm of the export volume of the treatment group after the milk scandal was significantly lower than that of the control group before the shock, while the import volume was significantly higher. The performance of different continents was heterogeneous. From the perspective of exports, after the milk scandal, China's exports to Asia of treatment group products were lower than those of control group products before the scandal, and the decline was the largest among all countries, followed by North America and Latin America. China's exports to the developed world also fell, not surprisingly, though not significantly. In contrast, after the milk scandal, Chinese exports of processed products to Oceania increased by 0.028. In terms of imports, China's imports of dairy products from Europe rose significantly by 0.351 since the scandal and also increased significantly by 0.333 from developed countries.

We have also added the Gross Domestic Product (GDP) of China, trade partners' GDP, exchange rate, transportation cost, trade barriers measurements (tariff and nontariff measures), common institutional quality (common legal), border (contiguity) and language and cultural (common official primary language) as the control variables. The GDP data come from World Development Indicators. The exchange rate was collected from the China Foreign Exchange Trading Centre. Transportation costs were constructed using data from World Bank Commodity Price Data and Centre for Prospective Studies and International Information (CEPII). Policy barriers cost data were calculated using the ESCAP World Bank trade cost database. All the common institutional, border, language and cultural data came from CEPII.

3.1.1 | GDP

For this variable, we included the total income in China (*GDP_China*) and the income of China's trade partner (*GDP_partner*). We have assumed that the volume of trade between the two countries is proportional to their GDP and that the larger the total GDP, the greater the variety of products consumed by consumers.

3.1.2 | Exchange rate (*Exchange rate*)

This includes the data of China and other countries or regions from 2002 to 2014, here expressed by indirect pricing; these data have come from the China Foreign Exchange Trading Centre.

3.1.3 | Transportation cost (*transcost*)

Following Hummels and Skiba (2004), we used the distance between China and the trade partner multiplied by the oil price to measure the transportation cost. Our measure would help cover the Washington Apple Effect, which states that trade products' quality improves significantly with increased transportation distance (Baldwin & Harrigan, 2011; Zhou et al., 2022).

TABLE 1 Summary statistics of the outcome variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Before treatment	Before control	Difference = (1)–(2)	Post-treatment	Postcontrol	Difference = (4)–(5)	Difference-in-Difference
Export							
Log of export	0.552 [2.544]	0.468 [2.332]	0.085 (0.086)	0.299 [1.888]	0.576 [2.611]	-0.277*** (0.087)	-0.361*** (0.123)
Log of export for Asia	0.441 [2.313]	0.351 [2.036]	0.090 (0.076)	0.235 [1.754]	0.382 [2.182]	-0.147** (0.075)	-0.238** (0.108)
Log of export for Africa	0.037 [0.667]	0.082 [0.985]	-0.044 (0.030)	0.000 [0.000]	0.082 [1.020]	-0.082*** (0.028)	-0.037 (0.041)
Log of export for Europe	0.010 [0.290]	0.022 [0.507]	-0.013 (0.015)	0.041 [0.542]	0.061 [0.815]	-0.020 (0.026)	-0.007 (0.029)
Log of export for North America	0.043 [0.704]	0.000 [0.000]	0.043** (0.018)	0.002 [0.076]	0.000 [0.000]	0.002 (0.002)	-0.041** (0.019)
Log of export for Latin America	0.000 [0.000]	0.007 [0.279]	-0.007 (0.007)	0.000 [0.000]	0.052 [0.727]	-0.052*** (0.019)	-0.045** (0.020)
Log of export for Oceania	0.000 [0.000]	0.007 [0.270]	-0.007 (0.007)	0.022 [0.468]	0.000 [0.000]	0.022* (0.013)	0.028** (0.014)
Log of export for developed countries	0.134 [1.233]	0.068 [0.901]	0.067* (0.038)	0.127 [1.129]	0.098 [1.059]	0.029 (0.042)	-0.037 (0.056)
Import							
Log of import	0.612 [2.525]	0.827 [3.060]	-0.215*** (0.099)	1.076 [3.685]	0.879 [3.358]	0.197 (0.134)	0.412** (0.163)
Log of import from Asia	0.145 [1.151]	0.111 [0.920]	0.035 (0.036)	0.117 [1.210]	0.089 [0.936]	0.028 (0.041)	-0.007 (0.055)
Log of import from Africa	0.011 [0.296]	0.002 [0.086]	0.008 (0.007)	0.005 [0.203]	0.000 [0.000]	0.005 (0.005)	-0.003 (0.010)

TABLE 1 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Before treatment	Before control	Difference = (1)–(2)	Post-treatment	Postcontrol	Difference = (4)–(5)	Difference-in-Difference
Log of import from Europe	0.298 [1.789]	0.479 [2.387]	-0.180** (0.074)	0.615 [2.820]	0.444 [2.398]	0.171* (0.100)	0.351*** (0.122)
Log of import from North America	0.036 [0.536]	0.056 [0.794]	-0.019 (0.024)	0.085 [1.058]	0.070 [0.987]	0.015 (0.039)	0.034 (0.044)
Log of import from Latin America	0.000 [0.000]	0.045 [0.708]	-0.045 (0.018)	0.111 [1.166]	0.126 [1.272]	-0.015 (0.046)	0.031 (0.047)
Log of import from Oceania	0.123 [1.315]	0.136 [1.453]	-0.013 (0.049)	0.144 [1.541]	0.150 [1.609]	-0.006 (0.060)	0.006 (0.077)
Log of import from developed countries	0.546 [2.423]	0.734 [2.940]	-0.187** (0.095)	0.882 [3.414]	0.737 [3.126]	0.146 (0.124)	0.333** (0.154)

Note: Standard deviations (errors) in brackets (parentheses).

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

3.1.4 | Trade policy barrier measurements

We used the tariff (*fta_wto*) and nontariff measures (*nontariff_tij*) to represent the cost of policy barriers. Tariff measures (*fta_wto*) will have a significant impact on the import and export of food products. We then used whether China had signed a free trade agreement (FTA) with its trading partner countries to express the tariff measures. The volume of trade between China and the countries that had signed the FTA will be even greater. Nontariff measures (*nontariff_tij*) are ad valorem equivalent trade costs, save for tariff in percent, which is based on Novy (2013) and is a trade cost measure based on microtheory.

3.1.5 | Common institution (*comleg_posttrans*)

This dummy variable represents the institution between China and its trade partner. *comleg_posttrans* has been set to 1 if China and its trade partner have common legal origins. Narita and Sudo (2021) show that legal origins have varying effects on political institutions today and have become an important determinant of today's institutions. As a result, institutions are more similar between countries that share a common legal origin, and institutional similarity benefits trade between the two countries.

3.1.6 | Contiguity (*contig*)

contig has been set to 1 if China and a trade partner share a border; otherwise, it is 0. A common border between the two countries will greatly reduce the cost of transportation, which has a positive significant impact on trade (Shahriar et al., 2019). In addition, a border between the two countries means that the culture and language of the two countries will be more similar, which also reduces the cultural cost of trade.

3.1.7 | Common language and culture (*comlang_off*)

This dummy variable captures whether China and a partner country have a common language; *comlang_off* has been set to 1 if the two countries have a common language and culture; otherwise, it is 0. Two factors are considered in selecting this variable. First, a common language can help reduce trade uncertainty between trading partners. This is conducive to promoting stable and smooth trading relations between countries (Egger & Lassmann, 2015; Jun et al., 2020; Lameli et al., 2015; Zhou et al., 2022). A common language can also significantly enhance the degree of trust between countries. The higher the degree of trust, the better the trade value of products between countries. In addition, we argue that cultural difference would be relatively stable between China and its trade partner, as shown by Spolaore and Wacziarg (2016), whose effect could be absorbed by country-year fixed effects.

The variables, definitions and summary statistics of the variables are listed in Table 2.

3.2 | Empirical strategy

To exploit the effect that China's milk scandal had on China's imports and exports, we specify the identification strategy based on the gravity model. The gravity model is considered the workhorse for econometric analyses of trade flows, essentially linking the bilateral value of trade between two countries to their economic size and the distance between them;

TABLE 2 Variables, definitions and summary statistics.

Variables	Definitions	Obs	Mean	Std. dev.	Min	Max
Ln (<i>Export</i>)	Log of export value	6006	0.477	2.369	0.000	17.043
Ln (<i>Import</i>)	Log of import value	6006	0.838	3.162	0.000	19.620
<i>Exqty</i>	Export quality index	3718	0.668	0.131	0.000	1
<i>Imqty</i>	Import quality index	6398	0.614	0.132	0.000	1
Ln (<i>GDP_China</i>)	Log of China's GDP	6006	29.211	0.370	28.601	29.749
Ln (<i>GDP_partner</i>)	Log of trade partner's GDP	5230	23.916	2.409	17.189	30.419
<i>Exchange rate</i>	The real exchange rate between China and her partner	5310	3.077	4.043	0.000	28.086
<i>Transcost</i>	Transportation cost	3543	289.274	144.059	49.177	1136.594
<i>fta_wto</i>	1 for free trade agreement	5564	0.086	0.281	0.000	1.000
<i>nontariff_tij</i>	Nontariff measures	5561	0.054	0.227	0.000	1.000
<i>comleg_posttrans</i>	1 for common legal origins after transition	5564	0.072	0.259	0.000	1.000
<i>contig</i>	1 for contiguity	5564	0.021	0.143	0.000	1.000
<i>comlang_off</i>	1 for common official of primary language	5564	65.529	39.001	2.018	202.643

it has been recently used extensively in the literature (Anderson, 2011; Dang & Xu, 2018; Head & Mayer, 2014; Shahriar et al., 2019). In 2008, a melamine scandal occurred in China's dairy industry and spread to various countries around the world through the media and the Internet. The scandal seriously affected China's international trade. The source of the scandal was infant formula, so a series of dairy products related to infant formula, including adult milk powder, pure milk and fermented yoghurt, were affected. However, butter and other milk-derived fats and oils not closely related to the product of milk were not affected as severely. Therefore, in this paper, dairy products with HS code 0401 related to the scandal are referred to as the 'treatment group', and those products with HS code 0405 are referred to as the 'control group'. In addition, we have analysed the impact of the scandal on the source of international trade through the triple DID strategy on the region and development levels, respectively.

Equation (1) presents our DID specification, which compares the value of trade of HS code 0401 (the treated types) with the value of trade of HS code 0405 6 years before and after 2008.

$$\log(\text{trade}_{ijt}) = \alpha + \beta \text{treat}_i \times \text{year08}_t + \lambda X_{ijt} + u_{jt} + \mu_{jt} + \varepsilon_{ijt} \quad (1)$$

where $\log(\text{trade}_{ijt})$ represents the logarithmic change in China's import or export of dairy products to other countries and regions in the world. Both dairy_i and year08_t are the dummy variables, where dairy_i takes 1 to represent dairy products with HS code 0401 and 0 to represent dairy products with HS code 0405; year08_t indicates whether the year was after the scandal. We also added the control variables X_{ijt} into the equation, which includes the GDP, exchange rate, transportation cost, policy barriers cost, common institutional, border, language and culture. u_{jt} and μ_{jt} stand for export country-year fixed effects and import country-year fixed effects, respectively. We controlled for export country-year fixed effects when China is an importer and import country-year fixed effects when China is an exporter. Furthermore, ε_{ijt} is the error term, and the clustered standard errors are used in the baseline regressions.

In the robustness checks, we first address the endogeneity issue of GDP, and the zero-trade problem. We further add alternative control variables into the regressions, and check the sensitivity of the significance level with robust standard error and clustered standard errors. Finally, the ordinary least square (OLS) estimation result is employed to compare with the results of the DID estimation strategy.

4 | EMPIRICAL RESULTS AND DISCUSSIONS

4.1 | Parallel trend and expected effect test

A potential challenge to the DID strategy is that differential changes between the treated and untreated groups may be driven by pre-existing differences in the time trends of normal trade. To validate the applicability of the DID model in this paper, before using the DID model to perform an estimation, it is necessary to take parallel trend tests to verify whether there has been any change in the trade value of the treatment and control groups before the dairy scandal in 2008. If there was a different change before the scandal, it cannot be excluded that the effect of the scandal estimated by the model was caused by the different changes before China's milk scandal.

Figure 3 shows the flexible tests of the pretrends for the treatment and control groups. We selected data from 2002 to 2014 for the parallel trend test, and we dropped 2002 as the base period to avoid the problem of multiple colinearity. Panel (a) of Figure 3 shows the parallel trend for China's milk exports, and Panel (b) illustrates the parallel trend for China's milk imports. We can observe an insignificant coefficient before 2008. Once China's milk scandal occurred, the differences between the control and treatment groups shifted significantly, for both exports and imports. The evidence from Figure 3 indicates that a parallel trend has been satisfied.

In addition, we have found further evidence in support of the common trend assumption regarding the effects of the milk scandal on exports and imports. We formally tested whether the pretrends for the two groups differed before 2008 by estimating more flexible regressions. Specifically, the following econometric model has been adopted:

$$\log(\text{trade}_{ijt}) = \gamma + \text{treat}_i \times Y_t + \lambda X_{ijt} + u_{jt} + \mu_{jt} + \varepsilon_{ijt} \quad (2)$$

where Y_t is the year dummy variable. The other variables and parameters are the same as those in Equation (1). Columns (1) and (4) in Table S2 present the difference in export and

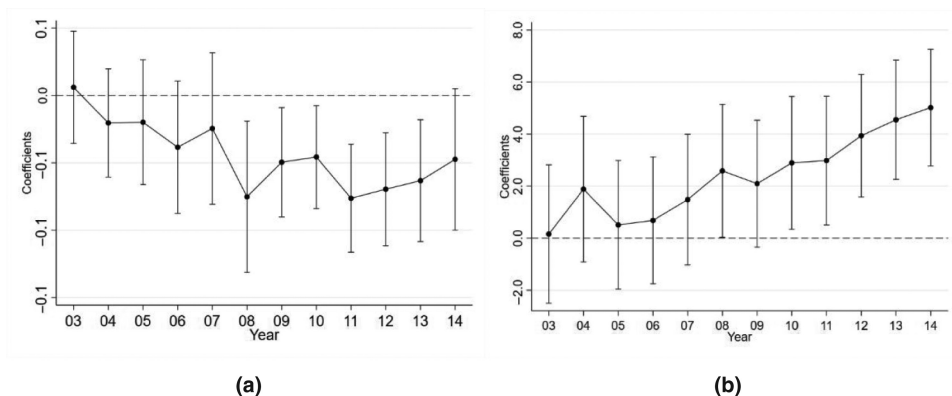


FIGURE 3 Tests of the pretrends for treated and untreated subclasses (Panel (a) for exports and Panel (b) for imports).

import values between the treatment and control groups from 2003 to 2014 after controlling for the variable $X_{i,t}$, respectively. The coefficients of $treat_i \times Y_{03}$ to $treat_i \times Y_{07}$ are not significant, indicating that the import and export values of the treatment and control groups did not change in the year before the milk scandal. After the scandal in 2008, the coefficients were significantly negative for the exports and significantly positive for the imports, which is in line with expectations. The parallel trends staying the same have further been confirmed by using econometric tests.

To further verify that the trade value does not have the expected effect before the impact of the milk scandal, we have performed an expected effect test using the milk scandal. We added $treat_i \times year06_t$ and $treat_i \times year07_t$ into Equation (1) separately to test whether the import and export of dairy products have the expected effects in 2006 and 2007. Both $year06_t$ and $year07_t$ are the dummy variables, and the definition method is the same as $year08_t$; that is, the value of 2006 or 2007 and later years is 1. Otherwise, it is 0. If the coefficient of $treat \times year06_t$ and $treat_i \times year07_t$ is significant, this indicates that the import and export values of dairy have the expected effect on the impact before the scandal. The results in Table S2 show that the coefficients of $treat_i \times year06_t$ and $treat_i \times year07_t$ are not significant, and the coefficient of the core variable $treat_i \times year08_t$ is still significant. Therefore, the import and export values of the treatment group before the milk scandal did not have a significant expected effect.

4.2 | Baseline results

Table 3 presents the benchmark DID regression results of the impact of the milk scandal on the dairy product trade in China. As shown in Columns (1) and (5), the significant coefficient suggests that the milk scandal impacted China's dairy trade, specifically by decreasing China's dairy product exports while increasing imports. Columns (2) to (4) and Columns (6) to (8) show the effect of the milk scandal on export and import volume after adding in the different control variables from Equation (1), respectively. The export volume decreased by 65.8%, and the import volume increased by 23.4% after adding year fixed and country-year fixed effects, which provides a lower bound effect, and the results remain significant at the 1% level. On average, the effect is larger than 35% reported by Dang and Xu (2018).⁵

The decrease in China's dairy exports and increase in imports reflect the importance consumers place on food safety and the demand for high-quality food. The impact of the milk scandal led consumers to losing trust in Chinese dairy products (Bánáti, 2011; Li et al., 2021) and downgrade their evaluation of the quality of Chinese milk relative to the milk produced in other countries (Luong et al., 2019), which led to an increase in dairy product imports and decrease in exports. This result is consistent with the findings of Luong et al. (2019).

Even after the food scandal, domestic consumers chose to buy dairy products from the international market rather than reduce their consumption. This is slightly different from other product scandals. The bovine spongiform encephalopathy (BSE) caused an extreme disruption in consumer demand for beef, and the sales of both domestic and imported beef dropped by 70% (Zielenziger, 2001). Losses in Australia and the United States, one of the major sources of beef imports to Japan, were as high as 50% (Ono, 2001). Although both countries were BSE-free, heavy damage was made to their exports. The rise in China's imported dairy products and the decline in China's exports also reflect the rigid demand for dairy products by consumers.

⁵In the DID regression model, we have calculated the effect by dividing the effect size by the mean of the dependent variables. Specifically, the export decrease effect is $-0.309/0.477 = -65.8\%$, and the import promotion effect is $0.196/0.838 = 23.4\%$.

TABLE 3 Impacts of China's milk scandal on China's total exports and imports.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log of export value				Log of import value			
$Post_{2008} \times Treat_i$	-0.309*** (0.054)	-0.324*** (0.065)	-0.432*** (0.081)	-0.432*** (0.081)	0.196* (0.109)	0.243* (0.135)	0.338* (0.184)	0.338* (0.184)
$\ln(GDP_China)$		0.518*** (0.164)	0.660** (0.250)	0.660** (0.250)		-1.017*** (0.224)	-2.168*** (0.472)	-2.168*** (0.472)
$\ln(GDP_partner)$		0.181** (0.072)	0.882*** (0.336)	0.882*** (0.336)		1.168*** (0.092)	1.033*** (0.294)	1.033*** (0.294)
<i>exchange</i> <i>rate</i>		0.010 (0.060)	0.096 (0.091)	0.096 (0.091)		0.089 (0.071)	0.111 (0.108)	0.111 (0.108)
<i>transcost</i>			-0.011* (0.005)	-0.011* (0.005)			0.016*** (0.004)	0.016*** (0.004)
<i>fia_wto</i>			-0.012 (0.324)	-0.012 (0.324)			0.822 (0.502)	0.822 (0.502)
<i>nonariff_tij</i>			-0.000 (0.000)	-0.000 (0.000)			0.000 (0.000)	0.000 (0.000)
<i>comleg_posttrans</i>				-2.464** (0.952)				12.425*** (2.041)
<i>contig</i>				-0.067 (0.881)				1.723** (0.582)
<i>comlang_off</i>				-2.534*** (0.813)				5.782*** (1.111)
Constant	-0.236** (0.088)	-17.346*** (2.206)	-40.963*** (6.480)	-40.896*** (5.963)	-0.328*** (0.065)	-10.510** (3.796)	19.995 (11.393)	18.272 (11.621)
Observations	6006	4852	3510	3510	6006	4852	3510	3510
R-squared	0.424	0.411	0.430	0.430	0.747	0.746	0.739	0.739

TABLE 3 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log of export value				Log of import value			
Import country FE	Yes	Yes	Yes	Yes	No	No	No	No
Import country-year FE	Yes	Yes	Yes	Yes	No	No	No	No
Export country FE	No	No	No	No	Yes	Yes	Yes	Yes
Export country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Columns (1)–(4) are the results of exports, while Columns (5)–(8) show the imports. Clustered standard errors are presented within parentheses, which are clustered at the year level. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

All models have controlled for the year fixed effects and the country-year fixed effects. Controlling for the year fixed effects can exclude common systemic factors that change over time. In addition, to reduce the omitted variable bias problem resulting from observable and unobservable variables that vary over time at the country level, we have also included export country-year and import country-year fixed effects. Controlling for the country-year fixed effect can also help address the multilateral resistance problem.

4.3 | Robustness checks

4.3.1 | The endogeneity of GDP

To verify the impact of the milk scandal on Chinese dairy products, a series of robustness checks were carried out. First, the endogeneity of GDP is a common issue in the trade literature. It is well known that trade is an important part of GDP, so there may be an endogenous problem of GDP in Equation (1). To deal with this issue, we took the population size as the proxy variable of GDP. That is, the control variables *GDP_China* and *GDP_partner* were replaced by *Population_China* and *Population_partner*, respectively. The results are shown in Columns (1)–(2) of Tables S3 and S4. Here, the impact of the milk scandal on trade did not change drastically, and its impact on China's export of dairy products was still negative, while imports increased.

4.3.2 | Zero trade values

Helpman et al. (2008) have pointed out that the problem of zero trade values will lead to biased estimation results when employing a gravity model. Therefore, we took some alternative approaches to address this issue. First, in Column (4) of Tables S3 and S4, we applied the Poisson method to test the effect of the milk scandal on China's imports and exports. The result is still significant, with the export inhibitory effect increasing to 0.577. Second, referring to the method used by Santos Silva and Teneyro (2006), the Poisson pseudo maximum likelihood estimator was used to regress the gravity model equation. The results are shown in Column (5) of Tables S3 and S4; these results are similar to those of the Poisson regression, which is also more in line with our expectations than the results in Tables S3 and S4.

4.3.3 | Adding more control variables and heteroscedastic issue at product level

We have included a range of covariates and fixed effects in the regression model to reduce omitted variable bias. To verify the validity of the model set, we transformed the fixed effects in the robustness test to verify whether the control variables are absorbed by the fixed effects. Column (5) of Tables S3 and S4 do not include any fixed effects, and Columns (6)–(7) include year fixed effect and country fixed effect. We find that the inclusion of fixed effects absorbs some of the unobservable omitted variables, but the model does not suffer from colinearity, and the results remain robust and consistent with Table 3 of the baseline regression.

In addition to whether a FTA is signed, the tariff rate appears to have a direct effect on trade flows. Therefore, we include bilateral tariffs in Column (9) of Tables S3 and S4 to reduce omitted variable bias, with robust results.

Finally, regarding the idiosyncratic errors that can have heteroskedasticity or autocorrelation—or both in the case of panel data—we show the clustering standard errors at the

product level in Column (8) of [Tables S3 and S4](#). The results are consistent with the standard errors of the benchmark regression robustness; hence, we can exclude the effect of heteroskedasticity.

4.3.4 | Government regulation

Stronger government regulations may exert the cost of trade and lead to a reduction in export volumes (Bai et al., 2022). After the 2008 scandal, several destinations imposed explicit import bans on Chinese dairy products, and some of these regulatory hurdles may have arisen from protectionist motives. [Table S5](#) lists these destinations that imposed import bans on Chinese dairy product. Therefore, to verify that changes in trade volumes were brought about by the milk scandal rather than government administrative regulations, we have dropped countries and regions that imposed restrictions on Chinese dairy products in [Tables S3 and S4](#) to exclude the effect of government regulations. Interestingly, the results, as shown in Column (10) of [Tables S3 and S4](#), are very similar to the baseline results. This suggests that although explicit government regulations existed, they cannot fully explain the scandal effect.

4.3.5 | Comparing with OLS regression results

As a robustness check, we also ran an OLS regression. Although the OLS regression is unidentified, it still provides a useful starting point for investigating the direction of bias in estimating how China's milk scandal affects trade. The naïve regression produces a smaller elasticity compared with our DID estimation. We show the OLS regression results for the classical gravity model in [Tables S3 and S4](#). Column (11) of [Table S3](#) shows that the marginal impact of scandal-affected dairy products on exports is negative compared with those products in the control group, which is broadly consistent with the DID estimation results. As shown in Column (11) of [Table S5](#), there is a significant positive relationship between the volume of dairy imports and whether they are contaminated products, with the coefficient remaining consistent with the results in [Table 3](#).

5 | THE HETEROGENEITY IMPACTS OF THE MILK SCANDAL ACROSS REGIONS

Considering that the milk scandal may have had different impacts on different regions because of the degree of regional economic development, consumer preference, customs and geographical locations, to further investigate the impact of the scandal on the purchasing choice of dairy products in the international market, we divided all countries or regions in the world into six parts, according to their geographical location: Asia, Africa, Europe, North America, Latin America and Oceania. At the same time, to investigate the differences in the impact of national economic development arising from the scandal, the countries were divided into two parts: developed countries and developing countries.⁶ Since the proposal of the Belt and Road Initiative, bilateral cooperation between China and the Belt and Road countries has continued to flourish and expand (Zhou et al., 2022). To measure the impact of China's milk scandal on trade between China and countries along the Belt

⁶The countries are classified into developed and developing countries based the development level definition of the World Bank in 2020, and the threshold value is \$2.995 GDP per capita (in constant 2000 USD).

and Road, we also added a dummy variable for Belt and Road countries. The following models were constructed:

$$\log(\text{trade}_{ijt}) = \tau + \zeta \text{treat}_i \times \text{year08}_i + \phi \text{dummy}_i + \psi \text{treat}_i \times \text{year08}_i \times \text{dummy}_i + \lambda X_{ijt} + u_{jt} + \mu_{jt} + \varepsilon_{ijt} \quad (3)$$

where dummy_i is the region's dummy variable or dummy variable of economic development and X_{ijt} is the control variable. Other variables and parameters are the same as those in Equation (1).

Tables 4 and 5 present the regression results of the heterogeneity tests from a different region of dairy product export and import, respectively. Columns (1)–(6), respectively, add region dummy variables and interactive items between $\text{Post}_{2008} \times \text{Treat}_i$ and the region dummy variables in both Tables 4 and 5. Because the coefficient estimates for different regions with DID interactions cannot be compared directly based on different models, we put these interaction terms of regions with DID in Column (7). In Column (8), the dummy variable of developed countries and their interactions with DID are added. We also include the interaction term between Belt and Road countries and DID in Column (9).

From Column (7) of Table 4, several conclusions about the degree of reaction of the different regions to the milk scandal can be drawn. First, after the scandal, the reduction in China's dairy exports was mainly concentrated in Asia, which is consistent with Figure S1. This may be because the quality of China's original exports to Asian countries was lower; other Asian countries responded the strongest to the milk scandal (Table S1), resulting in a sharp decline of Chinese dairy products exported to Asia. For example, India imposed a temporary ban on the import of milk and all milk-related products from China and extended this ban until 2019. Meanwhile, China's exports to Africa, North America and Europe also declined. After the melamine outbreak, the US and EU food risk warning systems responded quickly (Bánáti, 2011), with stringent testing and restrictions on products from China. For instance, the EU authorities stipulated tests for Chinese imports containing more than 15% of milk powder and announced a ban on all products for children coming from China that contained milk; the US Food and Drug Administration restricted imports of all Chinese food products containing milk (Bai et al., 2022). The decline in exports to Latin America was insignificant because China and the countries in Latin America had less dairy trade before the milk scandal, so the impact of the scandal was relatively small.

Second, it is surprising that China was exporting twice as many dairy products to Oceania as before. After the milk scandal, some countries stepped up inspections for Chinese imports, while others issued explicit import bans for products containing dairy ingredients from China (Bai et al., 2022); however, some countries in Oceania did not. Moreover, both the Chinese Government and dairy firms tightened controls on quality standards in the dairy industry, which meant exports to Oceania were of a higher quality.

In Column (8) of Table 4, we can see that China's export of dairy products to developed countries generally increased compared with developing countries and less-developed countries. This is mainly because of the higher quality of imports from developed countries (Hallak, 2006), while China's exports to developed countries were impacted less because of their relatively high quality. The results of Column (9) in Table 4 show that, after the shock, China's exports to Belt and Road countries decreased after the milk scandal because most of the countries along the Belt and Road are developing countries; this is contrary to the findings in Column (8) of Table 4. Moreover, the Belt and Road Initiative was proposed in 2013, and no country signed the agreement during the 2002–2014 period. China's trade volume with the Belt and Road countries was not affected by the Belt and Road Initiative, even though the Belt and Road Initiative was not even in place during this period.

Table 5 shows the international sourcing differences in the import of dairy; obvious regional differences can be seen in Column (7) of Table 5. China's dairy imports soared after the milk scandal (Figure S2). Among them, imports from Europe and Oceania grew exponentially and

TABLE 4 Heterogeneity effects of China's milk scandal on exports across regions.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log of export value									
$Post_{2008} \times Treat_i$	-0.142 (0.087)	-0.472*** (0.115)	-0.525*** (0.116)	-0.434*** (0.100)	-0.492*** (0.105)	-0.477*** (0.099)	0.067 (0.100)	-0.517*** (0.109)	0.078 (0.159)
Asia	1.795* (1.034)								
$Post_{2008} \times Treat_i \times Asia$	-1.023*** (0.236)						-1.261*** (0.246)		
Africa		-1.932* (1.054)							
$Post_{2008} \times Treat_i \times Africa$		0.141 (0.132)						-0.410*** (0.122)	
Europe			-5.070** (2.029)						
$Post_{2008} \times Treat_i \times Europe$			0.418*** (0.124)					-0.195* (0.116)	
NorthAmerica				-2.163 (1.934)					
$Post_{2008} \times Treat_i \times NorthAmerica$				0.144 (0.488)				-0.348 (0.486)	
LatinAmerica					-1.620 (1.195)				
$Post_{2008} \times Treat_i \times LatinAmerica$					0.423*** (0.150)				-0.106 (0.128)
Oceania						2.849 (3.516)			

(Continues)

TABLE 4 (Continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log of export value									
<i>Post₂₀₀₈ × Treat₁ × Oceania</i>						2.982*** (0.959)	2.438** (0.960)		
<i>Developed countries</i>								-4.854** (2.002)	
<i>Post₂₀₀₈ × Treat₁ × developed countries</i>								0.456** (0.186)	
<i>Belt and Road countries</i>									4.538** (1.944)
<i>Post₂₀₀₈ × Treat₁ × belt and road countries</i>									-0.661*** (0.172)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-49.840*** (11.366)	-38.852*** (11.013)	-41.866*** (10.852)	-40.930*** (10.845)	-43.267*** (11.182)	-41.415*** (10.893)	-51.540*** (11.700)	-41.942*** (10.874)	-47.100*** (12.102)
Observations	3510	3510	3510	3510	3510	3504	3504	3510	3510
R-squared	0.434	0.430	0.431	0.430	0.430	0.432	0.436	0.431	0.432
Import country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Columns (1)–(6) add interactive items between DID and region dummy variables. Column (7) adds a dummy variable of economic development and its interaction with the DID. Robust standard errors are presented within parentheses.

***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

TABLE 5 Heterogeneity effects of China's milk scandal on imports across regions.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log of import value									
$Post_{2008} \times Treat_i$	0.383*** (0.137)	0.529*** (0.147)	0.076 (0.107)	0.309*** (0.113)	0.365*** (0.115)	0.341*** (0.116)	-0.130 (0.096)	0.038 (0.095)	0.361 (0.287)
<i>Asia</i>	2.607*** (0.677)						0.368*** (0.179)		
$Post_{2008} \times Treat_i \times Asia$	-0.164 (0.203)								
<i>Africa</i>		-2.408*** (0.667)							
$Post_{2008} \times Treat_i \times Africa$		-0.684*** (0.144)					0.060 (0.094)		
<i>Europe</i>			16.260*** (2.513)						
$Post_{2008} \times Treat_i \times Europe$			1.069*** (0.310)				1.255*** (0.312)		
<i>North America</i>				26.550*** (3.101)					
$Post_{2008} \times Treat_i \times North America$				2.166 (1.527)			1.228 (0.866)		
<i>Latin America</i>					7.374*** (1.522)				
$Post_{2008} \times Treat_i \times Latin America$					-0.184 (0.318)		0.388 (0.885)		
<i>Oceania</i>						21.879*** (1.138)			

(Continues)

TABLE 5 (Continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log of import value									
$Post_{2008} \times Treat_1 \times Oceania$						-0.141 (0.410)	0.648* (0.385)		
<i>Developed countries</i>								15.275*** (2.414)	
$Post_{2008} \times Treat_1 \times developed\ countries$								1.473*** (0.380)	
<i>Belt and Road countries</i>									-19.492*** (2.528)
$Post_{2008} \times Treat_1 \times belt\ and\ road\ countries$									-0.029 (0.296)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	16.715* (9.395)	19.631** (9.109)	14.951 (9.151)	17.257* (9.224)	19.383** (9.329)	48.021*** (10.015)	14.754 (9.390)	13.214 (9.050)	37.662*** (9.552)
Observations	3510	3510	3510	3510	3510	3504	3504	3510	3510
R-squared	0.739	0.740	0.741	0.740	0.739	0.739	0.743	0.743	0.739
Export country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Columns (1)–(6) add interactive items between the DID and region dummy variables. Column (7) adds the dummy variable of economic development and its interaction with the DID. Robust standard errors are presented within parentheses.

***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

became the main sources of China's major dairy imports (Figure S2). This could be because Chinese consumers started preferring imported dairy products coming from higher quality international markets after the scandal (such as the EU, Australia and New Zealand; Zolin et al., 2021) because these products were perceived to be healthier and safer than domestic ones. China's imports from Asia and North and Latin America were also increasing, but they were far smaller than those from Europe and Oceania.

The results in Column (8) of Table 5 show that the import of dairy products almost doubled from developed countries after the milk scandal. The development of the dairy sector depends heavily on intensive agriculture and animal farming (Zolin et al., 2021), which is more advantageous in developed countries. Meanwhile, China was more inclined to import better-quality dairy products from markets such as Europe and Australia when it is decreasing dairy production failed to meet domestic demand after the milk scandal.

6 | A PLAUSIBLE EXPLANATION: THE ROLE OF PRODUCT QUALITY

6.1 | Quality estimation and explanation

We have found that dairy products exported from China to Asia were greatly affected, while the same products exported to Oceania increased. This may be because the quality of China's dairy product exports to Asian countries was lower and close to the quality of products involved in the domestic scandal. Asian countries adopted import bans to restrict imports from China (Table S4), resulting in a sharp decline in Chinese dairy products exported to Asia. In contrast, the quality of China's exports to Oceania was higher, so they were less affected. Likewise, China's imports from Europe and Oceania increased, perhaps because the dairy products in these markets were of higher quality and more suitable for the Chinese consumers' preferences after the milk quality scandal (Zolin et al., 2021).

To test our hypothesis, in this section, we have constructed a product quality index based on Khandelwal's (2010) nested logit model and Khandelwal et al.'s (2013) model (the KSW model). The nested logit model was mainly used to measure product quality at the national product level, starting with the consumer utility function of product quality, and the KSW model was used to measure quality, which can eliminate the demand price factor (Zhou et al., 2022). Therefore, we adopted the KSW model to measure dairy product quality.

We set the utility function of representative consumers in an importing country as follows:

$$U = \left[\int_{i \in \Omega} (\lambda_{jt}(i) q_{jt}(i))^{\sigma-1} di \right]^{\sigma/(\sigma-1)} \quad (4)$$

where Ω represents the dairy product variety clusters consumed by consumers in the importing country; $\lambda_{jt}(i)$ represents the quality of dairy products i ; $q_{jt}(i)$ is the importing country's demand for imported dairy products i ; σ indicates the elasticity of substitution between food types, $\sigma > 1$; and i and t represent the import source country and year, respectively. The budget constraint of importing countries is as follows:

$$\int_{i \in \Omega} p_{jt}(i) q_{jt}(i) di = Y_t \quad (5)$$

where Y_t indicates the total annual income of the importing country.

The demand equation has been obtained by maximising utility (Equation (4)) under the budget constraint (Equation (5)):

$$q_{jt}(i) = Y_t P_t^{\sigma-1} [\lambda_{jt}(i)]^{\sigma-1} [p_{jt}(i)]^{-\sigma} \quad (6)$$

where P_t represents the price index of the importing country:

$$P_t = \left[\int_{i \in \Omega} (p_{jt}(i)/\lambda_{jt}(i))^{1-\sigma} di \right]^{1/(1-\sigma)} \quad (7)$$

We can obtain Equation (8) by taking the logarithm on both sides of Equation (5):

$$\ln q_{jt}(i) + \sigma p_{jt}(i) = \ln Y_t + (\sigma - 1) \ln q_{jt}(i) + (\sigma - 1) \ln P_t \quad (8)$$

Then, we introduced the country fixed effect, year fixed effect and country-year fixed effect to control for the influence of year and country differences. Based on Broda et al. (2006) and Su et al. (2018), we set the import elasticity of substitution σ to 5 and the export elasticity of substitution in our analysis. By combining Equations (3) to (8), we have constructed the quality measurement as follows:

$$\ln q_{ijt} + \sigma p_{ijt} = \alpha_j + \alpha_t + \alpha_{it} + e_{ijt} \quad (9)$$

The quantity and price of dairy product i imported from country j in year t are represented by q_{ijt} and p_{ijt} ; α_j , α_t and α_{it} indicate the export country fixed effect, year fixed effect and export country-year fixed effect, respectively; e_{ijt} is the error term. We can obtain e_{ijt} through the OLS regression of Equation (9). Based on this, the quality calculation equation for imported dairy products has been constructed as follows:

$$quality_{ijt} = \ln(\lambda_{ijt}) = \hat{e}_{ijt} / (\sigma - 1) \quad (10)$$

Equation (10) can be used to calculate dairy products imported from the import source countries. We then standardised the dairy product quality obtained by Equation (10) because the KSW method cannot be comparable when it involves cross-time and cross-country comparisons. The quality standardisation equation is as follows:

$$rquality_{ijt} = \frac{quality_{ijt} - \min quality_{ijt}}{\max quality_{ijt} - \min quality_{ijt}} \quad (11)$$

In Equation (11), 'min' and 'max' imply the minimum and maximum value of the quality of dairy products for all years, respectively. The standardised quality obtained by Equation (11) is a ratio falling strictly within the interval [0,1] and does not have a measurement unit. Using Equation (11), comparisons can be made across periods and among countries.

To explore the effects that product quality has on China's exports and imports, we applied the DID method, as shown in Equation (12):

$$quality_{ijt} = \theta_i + \beta_1 dairy \times year08_t + \omega_{ijt} \quad (12)$$

where $quality_{ijt}$ is the dairy product i quality between China and its trade partner j in year t . ω_{ijt} is the idiosyncratic error term. The definitions of the other variables are the same as those

in Equation (1) because the DID method can be used to separate some nonproduct features. In addition, because of the unavailability of some data, the control variables were not added to Equation (12), and the most basic DID method has been used for regression.

Table 6 shows the role of product quality in the changes in China's dairy imports and exports after the milk scandal using the benchmark DID method. Columns (1)–(6) of Table 6 are the descriptive statistics of the subsamples, and Column (7) is the benchmark DID regression. As can be seen from Column (7), the quality of Chinese exports declined after the milk scandal. This coincides in part with Luong et al. (2018), who have suggested that consumer perceptions of milk quality in China were significantly lower than in other countries following the milk scandal, with a marginal utility equivalent to US\$4. The magnitude of the decline varied in different continents, in which dairy products exported to Asia suffered the largest decline in quality. After the milk scandal, Asian countries imposed strict restrictions on dairy imports from China, suggesting that Asian countries had a greater perception of the milk scandal, which reduced the perceived quality of Chinese dairy products by consumers and brought about a decline in the quality and trade of Chinese exports to Asia. Column (7) of Table 6 shows that the quality of Chinese products was lower than before. In contrast, the quality of Chinese products exported to Oceania increased significantly. Hallak (2006) has found that rich countries tend to import relatively more from countries that produce high-quality products, which is partly evidenced by the increase in Chinese dairy products exported to Oceania after the milk scandal.

The quality of dairy products imported into China generally increased because the Chinese Government was increasingly giving attention to the quality of imported food because of food safety concerns (Zhou et al., 2022). China's Government tightened inspections of domestically produced food products. Dairy firms also tightened their standards for purchased raw milk, and some started to build their upstream milk farms to better monitor and control quality (Bai et al., 2022). The increase in China's dairy exports to developed countries and Oceanian regions could be driven by the imposed regulations that led to higher product quality. Developed countries have more stringent regulations than developing countries. Consumers in developed countries fully trust the strict inspection and testing of imported goods by national customs. Therefore, developed countries have the least impact on the consumption demand for dairy products in China. In addition, Chinese exporters tended to decrease the dairy price. Under the premise of ensuring the quality of dairy products, developed countries were more willing to import dairy products from China, especially with the reduced price.

The quality of imported products also showed regional differences. Specifically, the quality of China's imports from Europe improved, while the quality of other import source countries did not change significantly. Therefore, product quality can partly explain the increase in Chinese dairy products exported to Oceania, as well as the increase in dairy products imported from Europe.

In addition, changes in China's imports and exports after the milk scandal were also influenced by media factors. China's exports to neighbouring countries might have been influenced by the media (Chen & Feng, 2018), amplifying the effect (Luong et al., 2019). However, we did not include the variable of media because these data were not available. However, even adding in this variable, the effect of product quality provides a lower bound because media magnifies the effect further.

6.2 | Robustness checks

6.2.1 | Different flexibility of substitution

In this paper, there is a specific value for the product elasticity of substitution in the measurement of product quality, which changes when different elasticity values are used. However, the product quality measurement will change when using a different value of σ . The regression results could be biased if we ignore different values of σ . To eliminate the possibility of

TABLE 6 Role of product quality in dairy exports and imports.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Before treatment	Before control	Difference=(1)-(2)	Post- treatment	Postcontrol	Difference=(4)-(5)	Difference-in-Difference
Quality of export	0.508 [0.080]	0.469 [0.093]	0.040*** (0.013)	0.470 [0.103]	0.502 [0.110]	-0.032 (0.020)	-0.071*** (0.023)
Quality of export for Asia	0.371 [0.234]	0.336 [0.239]	0.036 (0.040)	0.306 [0.239]	0.288 [0.256]	0.018 (0.052)	-0.017 (0.065)
Quality of export for Africa	0.032 [0.124]	0.096 [0.197]	-0.064** (0.027)	0.000 [0.000]	0.069 [0.169]	-0.069** (0.028)	-0.005 (0.040)
Quality of export for Europe	0.013 [0.073]	0.035 [0.121]	-0.022 (0.017)	0.112 [0.202]	0.079 [0.213]	0.034 (0.044)	0.055 (0.041)
Quality of export for North America	0.043 [0.151]	0.000 [0.000]	0.043** (0.019)	0.002 [0.012]	0.000 [0.000]	0.002 (0.002)	-0.040* (0.023)
Quality of export for Latin America	0.000 [0.000]	0.008 [0.062]	-0.008 (0.007)	0.000 [0.000]	0.063 [0.166]	-0.063** (0.028)	-0.055** (0.024)
Quality of export for Oceania	0.000 [0.000]	0.007 [0.060]	-0.007 (0.007)	0.040 [0.137]	0.000 [0.000]	0.040** (0.018)	0.048*** (0.017)
Quality of export for developed countries	0.134 [0.230]	0.083 [0.182]	0.051 (0.036)	0.245 [0.242]	0.115 [0.243]	0.131** (0.051)	-0.080 (0.060)
Quality of import	0.558 [0.136]	0.630 [0.123]	-0.071*** (0.017)	0.590 [0.131]	0.607 [0.106]	-0.017 (0.016)	0.054** (0.023)
Quality of import from Asia	0.164 [0.287]	0.123 [0.242]	0.041 (0.036)	0.083 [0.232]	0.079 [0.196]	0.005 (0.030)	-0.036 (0.047)
Quality of import from Africa	0.015 [0.102]	0.003 [0.035]	0.011 (0.010)	0.005 [0.055]	0.000 [0.000]	0.005 (0.005)	-0.006 (0.011)
Quality of import from Europe	0.264 [0.283]	0.351 [0.339]	-0.087** (0.043)	0.336 [0.308]	0.302 [0.310]	0.033 (0.043)	0.120** (0.061)

TABLE 6 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Before treatment	Before control	Difference = (1)–(2)	Post- treatment	Postcontrol	Difference = (4)–(5)	Difference-in-Difference
Quality of import from North America	0.036 [0.131]	0.044 [0.168]	-0.007 (0.021)	0.047 [0.164]	0.052 [0.184]	-0.005 (0.024)	0.003 (0.032)
Quality of import from Latin America	0.000 [0.000]	0.035 [0.146]	-0.035** (0.015)	0.061 [0.178]	0.095 [0.232]	-0.034 (0.028)	0.002 (0.032)
Quality of import from Oceania	0.541 [0.061]	0.663 [0.021]	-0.121*** (0.017)	0.551 [0.032]	0.644 [0.058]	-0.083*** (0.019)	0.038 (0.025)
Quality of import from developed countries	0.474 [0.206]	0.533 [0.263]	-0.059* (0.033)	0.468 [0.276]	0.491 [0.258]	-0.024 (5.000)	-0.035 (0.049)

Note: Standard deviations (errors) in brackets (parentheses).

*** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

biased results, we set the export elasticity of substitution and import elasticity of substitution to 5 and 8, respectively, in Equation (10) (Zhou et al., 2022), and we recalculated the export and import quality of milk products. The regression results under different parameter values of σ can be seen in Panel A of Tables 7 and 8; the regression results of the main variables' significance remain unchanged with different values of σ and are still highly significant. This confirms the robustness of the benchmark results when using a specific value of σ .

6.2.2 | Testing by a nonstandardised product

In the benchmark regression model, we standardised the food quality. The standardisation process resulted in quality levels that were different from the prestandardisation levels. To test whether the benchmark regression results would show significant heterogeneity because of quality standardisation, we used a nonstandardised food quality measure to rerun our regression. The results are shown in Panel B of Table 7. The results remain stable after applying a nonstandardised measure of product quality. This confirms the robustness of the primary regression results regarding the standardisation of product quality.

6.2.3 | Considering product differentiation

We used the two main categories of HS four-digit products in the benchmark regression, but given the variability of the products, we have included a more specific level of HS eight-digit products, which are listed in Table S6. Panel C of Tables 7 and 8 shows the regression results after including the segmented products, which remain largely consistent with Table 6.

7 | CONCLUDING REMARKS

Food fraud, which is a serious public health issue, has been attracting attention in recent years (Soon & Liu, 2020; Stevens et al., 2018). The literature has shown that food scandals not only decrease a firm's market share (Burton & Young, 1996) and a firm's performance (Heerde et al., 2007), but also negatively impact the reputation of enterprises (Breitenbach et al., 2018), leading to changes in consumers' expenditure distribution on those products (Gao et al., 2020; Hoffmann et al., 2019). However, the effects of food scandals on international trade and international sourcing have received little attention. To fill this research gap, the current paper has uncovered the effects of the milk scandal on international trade by using China's milk scandal in 2008 as a natural experiment. We applied long panel data between 2002 and 2014 to apply the DID approach. The DID estimations show that the outbreak of the milk scandal led to larger imports, which increased by 23.4%, damaging the total exports of dairy products from China, which dropped by 65.8% in the year after China's milk scandal.

In addition, our research fills the gap in the literature regarding the heterogeneous impact of food scandals on trade between countries of origin and different countries or regions. The empirical evidence reveals that a reduction in exports was mainly concentrated in Asia, while dairy products exported to Oceania increased. The increase in imports was mainly concentrated in high-quality markets, such as Europe and Oceania, which is consistent with consumers' preferences for high-quality products. We found that the quality of China's dairy product exports to Asian countries was lower and that Asian countries adopted import bans to restrict imports from China, resulting in a sharp decline in Chinese dairy products exported to Asia. In contrast, the quality of China's exports to Oceania was higher, so they were less affected. Likewise, China's imports from Europe and Oceania increased because the dairy product of this market was higher and more suitable for Chinese consumers' preferences after China's milk scandal.

TABLE 7 Robustness checks: export.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Quality of export	Quality of export for Asia	Quality of export for Africa	Quality of export for Europe	Quality of export for North America	Quality of export for Latin America	Quality of export for Oceania	Quality of export for developed countries
A. Different flexibility of substitution								
DID	-0.071*** (0.024)	-0.017 (0.065)	-0.005 (0.036)	0.055 (0.046)	-0.040** (0.017)	-0.055** (0.022)	0.048** (0.024)	-0.080 (0.061)
Observations	288	240	240	240	240	240	240	240
R-squared	0.035	0.019	0.048	0.053	0.050	0.082	0.050	0.052
B. Nonstandardised quality								
DID	-0.357*** (0.116)	-0.113 (0.105)	0.010 (0.016)	-0.108* (0.059)	-0.082* (0.042)	0.000 (0.007)	0.001*** (0.000)	-0.193** (0.092)
Observations	288	240	240	240	240	240	240	240
R-squared	0.035	0.013	0.013	0.040	0.028	0.000	0.006	0.022
C. More products								
DID	-0.095*** (0.028)	-0.106* (0.062)	0.028 (0.029)	-0.065** (0.033)	-0.058*** (0.018)	-0.031* (0.017)	0.055** (0.021)	-0.113** (0.052)
Observations	903	711	711	711	711	711	711	711
R-squared	0.021	0.014	0.052	0.051	0.034	0.030	0.024	0.039

Note: Robust standard errors are presented within parentheses. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

TABLE 8 Robustness checks: import.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Quality of import	Quality of import for Asia	Quality of import for Africa	Quality of import for Europe	Quality of import for North America	Quality of import for Latin America	Quality of import for Oceania	Quality of import for developed countries
A. Different flexibility of substitution								
DID	0.054** (0.023)	-0.036 (0.047)	-0.006 (0.012)	0.120** (0.060)	0.003 (0.032)	0.002 (0.032)	-0.026 (0.038)	0.035 (0.049)
Observations	476	429	429	429	429	429	429	429
R-squared	0.041	0.019	0.008	0.011	0.001	0.040	0.002	0.011
B. Nonstandardised quality								
DID	0.206** (0.087)	-0.085 (0.496)	0.344 (0.320)	-0.469 (0.411)	0.024 (0.099)	-0.079 (0.100)	0.016 (0.121)	-0.342 (0.455)
Observations	476	422	422	422	422	422	422	422
R-squared	0.041	0.004	0.007	0.006	0.001	0.003	0.052	0.010
C. More products								
DID	0.045*** (0.013)	-0.008 (0.024)	-0.011 (0.008)	0.073** (0.034)	0.015 (0.016)	0.022 (0.014)	-0.046* (0.024)	0.024 (0.026)
Observations	1970	1752fu	1752	1752	1752	1752	1752	1752
R-squared	0.071	0.017	0.005	0.012	0.001	0.017	0.003	0.007

Note: Robust standard errors are presented within parentheses.

***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Our research has policy implications for dealing with food scandal shocks in international trade. The impact of the food scandal has asymmetric impacts on imports and exports, implying that the government should balance the interests between producers and consumers simultaneously in this context of asymmetric impacts. The government should also diversify the importing sources and exporting destinations when facing food scandals because diversification could help mitigate these scandal risks (Regolo, 2013). For the Chinese Government and industry associations, it is important to implement stricter dairy regulations and establish a sound inspection system to further improve the quality of imported and exported dairy products.

Our paper has two limitations, which we leave to future exploration. In our paper, we only applied China's milk scandal as a natural experiment to identify the heterogeneous responses of importers and exporters. Critical readers may be concerned that other food scandals might be invalid and that those producers and consumers may have different responses compared with China's milk scandal. Thus, simultaneously analysing food scandals within a single framework is worth studying in future. The second issue is that the Chinese trillion-dollar global strategy—namely the Belt and Road Initiative—significantly improved the quality of food, as documented by Zhou et al. (2022). In our paper, we have found that the Belt and Road Initiative mattered for milk imports and exports, but the Belt and Road Initiative-related countries did not share the milk scandal risk with China. This may be attributed to a one-year data-overlapping issue. In our paper, our sample covered only the years between 2002 and 2014. There was only 1 year of data that overlapped with the Belt and Road Initiative, which started in 2013. An interesting avenue for future work would be to extend the data range to explore the food scandal risk-sharing mechanism with Belt and Road countries.

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DATA AVAILABILITY STATEMENT

The data 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.

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