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Research on the Implementation of the Quality Traceability System on the Global Meat Import Trade

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Abstract: A complete traceability system is a manifestation of efficiency and technological innovation in agricultural trade, and has now become one of the key factors affecting global meat trade. Among them, implementing the traceability standard is a crucial indicator to evaluate the completeness of the system construction in various countries. Based on the analysis of the theoretical mechanism, the empirical part introduces global meat product recalls. The number of meat notifications as evaluation indicators for the traceability system implementation divides the research objects into high- and middle-income countries. It uses the trade gravity expansion model to discuss the impact of implementing the quality traceability system on global meat trade imports. The study found that the economic development level of both sides of the trade has a significant role in promoting meat trade imports. The factors such as trade distance, export population size, and exporting country exchange rates have a significant negative impact on meat trade imports. As a quantitative index of the traceability system, the results of the study are in line with expectations. Therefore, my country should actively expand the scale of meat production, enhance economic vitality and technological innovation, build an efficient traceability system, maintain the stability of exchange rates and meat prices, improve the transaction efficiency of the meat trade, and enhance the competitiveness of meat products export trade.

1. Introduction

Developed nations boast well-established agricultural traceability systems, which ensure the quality of domestic agrarian produce and raise the bar for the quality standards of imported goods. The theoretical framework of a robust traceability system within a country theoretically fosters agricultural product exports and bolsters bilateral trade[1]. Traceability entails the capacity to track the upstream and downstream paths of products along the supply chain to glean specific information regarding their origin and attributes[2]. Manzini and Accorsi (2013) assert that an effective traceability system not only upholds food safety but also efficiently manages product supply chains[3]. Regarding traceability technology and its applications, Ruiz-Garcia et al. (2010) have developed prototype systems utilizing information technologies like trackers and quality testing. These systems allow convenient access to information concerning various stages of agricultural production, storage, transportation, wholesale, and retail via the network[4]. Regarding the acceptance of traceability systems, Kim and Woo (2016) examined individuals' willingness to utilize QR codes to query food traceability systems. By incorporating variables such as Perceived Information (PI) and Food Involvement (FI) and employing the Technology Acceptance Model (TAM), they confirmed that fundamental perceived variables such as usefulness and ease of use significantly influence consumers' willingness to adopt QR technology for food traceability systems[5]. Concerning the measurement of traceability system implementation efficiency, Mejia et al. (2010) conducted a cost analysis of various technological elements required for constructing traceability systems. Their finding affirms that completing traceability systems can expedite product tracing and restore consumer confidence[6]. Chen et al. (2016) and Wang et al. (2017) delved into the decision-making behaviors of entities involved in agricultural product quality and safety traceability systems. They suggested that the key to effectively implementing food traceability systems lies in understanding the dynamic behaviors of consumers, farmers, and enterprises during the implementation process[7-8]. To evaluate and optimize traceability system performance, Dabbene and Gay (2011) introduced new standards and methods for measuring and optimizing traceability system performance. They proposed that restricting the number of recalled products to a minimum serves as a means of evaluating the efficiency and effectiveness of traceability systems, thereby validating the efficacy of using recall numbers as a measure of traceability system implementation strength[9].

In empirical research, gravity models are predominantly employed to assess the efficiency and potential of agricultural trade. Ding et al. (2019) and Li et al. (2019) utilized time-varying stochastic frontier gravity models and export inefficiency models to analyze the factors affecting China's agricultural trade potential and export efficiency with five Central Asian countries and countries along the Silk Road Economic Belt [10-11]. Deng et al. (2015) applied a general gravity model to estimate China's export trade potential with 39 economies across Eurasia [12]. Geng (2015), employing an extended gravity model, investigated China's bilateral agricultural trade potential with emerging economies from both aggregate and sectoral perspectives [13]. Studies employing gravity models to measure agricultural trade relationships and influencing factors include Xie et al. (2016), who conducted a multidimensional analysis of agrarian trade relations between China and TPP member countries, and Lu et al. (2017), who analyzed the factors influencing agricultural trade between China and 12 emerging market countries using an extended trade gravity model [14-15]. Zhang et al. (2016) utilized principal component analysis and a comprehensive gravity model to analyze the impact of trade facilitation on bilateral trade between the Silk Road Economic Belt and China [16]. Research focusing on measuring agricultural trade costs and effects includes Liu et al. (2018), who used the World Bank's Trade Costs Dataset and applied the gravity model for GMM estimation to analyze China's agricultural trade cost characteristics, highlighting the significant role of trade facilitation in reducing agricultural trade costs [17]. Wang et al. (2016) evaluated China's international competitiveness in sheep meat by analyzing production costs, export prices, and relevant global competitiveness indices. They employed the gravity model and Heckman two-stage model to quantify the impact of trade inefficiency factors on China's sheep meat exports [18]. Chen et al. (2018) discussed various methods for estimating the trade effects of SPS measures, including cost-benefit analysis, partial equilibrium analysis, general equilibrium analysis, and gravity model analysis [19]. Dong et al. (2015) studied the trade effects of SPS measures based on the New New Trade Theory, applying panel data on agricultural imports from developed countries to an extended gravity model. They suggested that China could enhance SPS notification levels to increase quality requirements for agricultural imports and improve national welfare [20]. Xia and Glynn (2019) incorporated the number of SPS notifications as an explanatory variable into the gravity model to discuss trade model estimates for beef and pork under different SPS quantification schemes. They argued that SPS measures appear more like trade barriers than catalysts for agricultural trade and discussed cross-industry spillover effects on industry trade [21]. Hence, incorporating SPS as a positive indicator of traceability system implementation strength into the gravity model could be considered. Guo et al. (2014) analyzed the impact of SPS measures on China's poultry product exports by correcting trade zeros and applying the gravity model, exploring the influence of trade measures, FTAs, and safety standards on meat trade [22].

2. Research Design

2.1 Research Approach

Empirical research methods such as the dummy variable method and index analysis are predominantly employed to measure the impact of traceability systems on agricultural trade effects. Among these methods, traceability system implementation strength assessment can be evaluated using indicators such as the number of product recalls by exporting countries [9] and the latest WTO trade notification on SPS [21]. The development of traceability systems in high-income countries like the United States, Germany, Japan, South Korea, and the United Kingdom has been earlier and more comprehensive compared to middle- and low-income countries. The stringent traceability quality requirements in high-income countries are key factors influencing bilateral meat trade flows. As a result, differences in economic scale, traceability system implementation strength, and trade costs lead to varying degrees of impact on the external trade flows of major meat trading nations worldwide. This study is based on the World Bank's classification of countries into high and middle-income categories, combined with the global meat trade's scale, structure, and international distribution. Five major high-income countries and five major middle-income countries are selected as sample countries for analysis. Considering data significance and validity, the top ten importing countries for meat trade are selected as trading partners for each country. The period covers 2010 to 2019, with 1000 observations for each unit variable and a total sample size of 9000.

2.2 Model Design

In this study, the standard indicators of traceability systems are regarded as trade inefficiency factors, and based on the perspective of meat trade imports, the collinearity and correlation of relevant variables are examined. The extended gravity trade model is applied to focus on the impact of traceability systems on meat trade in countries of different income levels. Mixed regression, random effects, and GLS estimation tests are conducted on relevant variables. The gravity trade model refers to the unilateral trade flow between two countries being directly proportional to their respective economic sizes and inversely proportional to the distance between them (Anderson, 1979) [23]. Therefore, the study considers economic size as representing the supply and demand capacity of importing and exporting countries, serving as a trade driving force, while trade distance represents trade resistance. The logarithmic expression of the traditional gravity trade model is:

$$ln\, X_{ii} = \beta_0 + \beta_1\, ln\, GDP_i + \beta_2\, ln\, Distance_{ii} + \mu_{ii} \tag{1}$$

In this context, it X_{ii}represents the trade flow between country i and country j, GDP_i denotes the gross domestic product of the exporting country, and $Distance_{ii}$ signifies the trade distance between the two parties. β_0, $\beta_1$and β_2 are regression coefficients, while μ_{ii} stands for the standard random error.

Considering the real-world dynamics of global meat trade supply and demand, this study introduces five explanatory variables sequentially into the original model: the total population of the exporting country, the official exchange rate of the exporting country, global meat recall volume, global meat notification quantity, and the level of economic development of the exporting country. Consequently, the following extended gravity trade model is derived:

$$\ln IMP_{ijt} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln Distance_{ij} + \beta_3 lnPOP_{jt} + \beta_4 lnRATE_{jt+} \beta_5 lnREC_{jt} + \beta_6 lnSPS_{jt} + \beta_7 Develop_{jt} + \mu_{ijt} \quad (2)$$

In this context, i represents the importing country of meat products, j represents the exporting country of meat products, and IMP is the dependent variable, representing the total trade value of country ii importing meat products from country j in year t, measured in thousands of US dollars. The meanings and symbol predictions of other explanatory variables are briefly explained in the table 1 below:

Table 1: Prediction and Explanation of Explanatory Variables

Explanatory Variable	Predicted Symbol	Meaning	Data Source
GDP_{it}	+	Per capita Gross Domestic Product of importing country i (Unit: constant-price US dollars)	World Bank Database
$Distance_{ij}$	-	Weighted trade distance between importing and exporting countries (Unit: kilometers)	French Center for International and Strategic Studies Database
POP_{jt}	-	Total population of exporting country j in year t (Unit: individuals)	World Bank Database
$Rate_{jt}$	-	Official exchange rate of exporting country j in year t (denominated in US dollars, period average)	World Bank Database
REC_{jt}	-	Number of meat product recalls in exporting country j in year t	Organization for Economic Co-operation and Development Global Recall Database
SPS_{jt}	+	Number of meat product notifications in exporting country j in year t	World Trade Organization TBT-SPS Database
$Develop_{j}$	+	The development level of exporting country j	World Bank Database

2.3 Model Verification and Results Analysis

Fitting random effects models to panel data, the study employs the Generalized Least Squares (GLS) estimation method for multiple linear regression analysis. Considering each variable's goodness of fit and robustness, seven explanatory variables are introduced based on the basic model, including per capita GDP, bilateral trade distance, total population, official exchange rate, global meat recall volume, global meat notification quantity, and economic development level. According to the regression results of the basic Model 1 in Table 2, variables such as per capita GDP, bilateral trade distance, and total population are significant at the 1% confidence level. Additionally, the Chi-squared value of 1716.57 in the Wald test indicates the statistical significance of the model. With the inclusion of variables, as shown in the regression results of expanded Model 5 in the table, the Chi-squared value of the Wald test steadily increases, and the structure remains consistent with

Model 1. All variables remain significant at the 1% confidence level, indicating the robustness of the econometric results.

Table 2: Regression Results of Model Variables

Explanatory Variables	Basic model	Explanation model			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
constant	0.831*	1.934***	0.994*	8.060***	13.685***
	-1.687	-3.553	-1.923	-12.775	-12.677
lnGDP	1.328***	1.337***	1.331***	1.341***	0.781***
	-40.216	-39.495	-41.947	-32.996	-7.669
lnDIST	-0.083***	-0.171***	-0.175***	-0.571***	-0.605***
	(-4.811)	(-7.875)	(-7.679)	(-23.314)	(-21.892)
lnPOP	-0.106***	-0.125***	-0.054***	-0.338***	-0.362***
	(-6.101)	(-6.567)	(-2.856)	(-14.795)	(-14.471)
lnRATE		-0.102***	-0.146***	-0.166***	-0.155***
		(-5.847)	(-7.682)	(-8.170)	(-6.375)
lnREC			-0.089***	-0.058***	-0.071***
			(-7.805)	(-5.329)	(-5.677)
lnSPS				0.520***	0.536***
				-31.122	-27.712
Develop					1.102***
					-6.545
Obs.	1000	1000	1000	1000	1000
Wald chi2	1716.57***	1800.73***	1997.08***	3143.16***	3000.85***

3. Analysis of Results and Findings

From model (3), it is evident that among the factors influencing the import volume of meat trade in sample countries, the order of influence from greatest to least is as follows: the economic development level of the exporting country, the per capita GDP of the importing country, bilateral trade distance, the number of meat product notifications from the exporting country, the total population of the exporting country, the official exchange rate of the exporting country, and the global meat recall volume of the exporting country. Combining the analysis of relevant influencing factors from the model, the following observations can be made:

In terms of economic development level, higher economic development in the exporting country, all else being equal, indicates a more robust traceability system in that country, leading to greater demand for its imports by the importing country. For countries with relatively lower levels of development, their meat exports to importing countries are, on average, 1.1% higher. Moreover, for every 1% increase in the per capita GDP of the importing country, meat trade imports increase by 0.78%, indicating that larger economies tend to have higher meat demand, thus exerting a stronger trade attraction.

Regarding trade costs, firstly, for every 1% increase in bilateral trade distance, meat trade imports in the importing country decreased by 0.61%, indicating that greater trade distance between exporting and importing countries leads to higher logistics costs in the traceability system, which is detrimental to trade imports, highlighting the significant inhibitory effect of trade spatial distance on meat trade volume. Additionally, for every 1% increase in the total population of the exporting country, meat trade imports in the importing country decreased by 0.36%, suggesting that countries with higher domestic meat consumption have smaller meat export volumes due to limited supply capacity, indicating a significant inhibitory effect of population factors on meat trade. The increase in trade costs and the reduction in trade volume reflect a suppression effect on meat trade volume by increasing the unit cost of traceability system operations in the global meat trade.

In terms of traceability system effectiveness, the number of product recalls from the exporting country serves as an indicator of traceability system effectiveness. The greater the number of product recalls, the weaker the traceability system execution in the exporting country. In quantitative terms, for every 1% increase in product recalls of meat products from the exporting country, meat trade imports in the importing country decrease by 0.07%. Conversely, a higher number of SPS notifications from the exporting country indicates stricter traceability system requirements, with a 1% increase in meat product notification resulting in a 0.54% increase in meat trade imports in the importing country, verifying that higher SPS notifications indicate more robust traceability system execution in the exporting country, which is conducive to meat product trade exports.

Furthermore, considering other trade-influencing factors such as the exchange rate of the exporting country, all else being equal, for every 1% increase in the exporting country's exchange rate in US dollars, the corresponding meat trade imports decrease by 0.16%. The rise in the exporting country's currency exchange rate reflects an increase in meat prices, and more significant fluctuations in meat product prices are detrimental to the export of meat products from the exporting country.

In conclusion, a robust traceability system and its execution in the exporting country are catalysts for the bilateral meat trade. The primary factors influencing bilateral meat trade include the per capita GDP of the importing country, trade distance, population size, exchange rate, global meat product recall volume, SPS notification quantity, and the economic development level of the exporting country. The traceability system significantly affects meat trade imports in countries with different income levels. From the perspective of trade costs, increases in the population size of the exporting country, bilateral trade distance, and exchange rate fluctuations have been shown to weaken the promoting effect of the traceability system on meat trade. Thus, improving the existing traceability system in the exporting country, reducing trade costs at various stages, and stabilizing meat prices can enhance meat trade efficiency, maintain competitiveness in meat exports, and promote bilateral meat trade.

4. Conclusions

To enhance China's agricultural product traceability system and strengthen its competitiveness in meat trade exports, the following policy recommendations are proposed:

Firstly, China could draw on advanced experiences from developed countries to refine its agricultural product traceability system. From the perspective of supply chain construction, China could learn from advanced practices such as the U.S. National Animal Identification System (NAIS), Canada's Can-Trace, and the EU's comprehensive agricultural safety management system to ensure full traceability of meat products using a globally unified coding system. In terms of system requirements and standards, China could adopt advanced traceability system standards, such as Good Agricultural Practices (GAP), Hazard Analysis and Critical Control Points (HACCP) certification systems, and food supply traceability systems, to achieve standardized integration of the industry chain and improve the quality of traceability information. By improving regional, industry, and national-level agricultural product traceability information platforms, China can establish a timely, accurate, and efficient information monitoring and notification system to achieve information sharing and traceability throughout the entire industry chain.

Secondly, international collaboration on traceability system platforms should be pursued to create a global information platform for traceable products. Given that China's meat exports account for a significant share of trade with developed countries such as the EU, the U.S., and Japan, differences in traceable logistics systems and standards pose technical trade barriers to China's meat trade at the export stage. Therefore, China should strengthen international logistics cooperation to reduce the costs of traceable logistics and coordinate multiple departments to leverage market advantages, establishing an information-sharing and efficient traceability system for meat agricultural product logistics. Given the lack of initiative and weak execution among relevant stakeholders, governmental support should be increased at the fiscal level to share trade logistics costs, establish regional agricultural product logistics traceability information management platforms, and achieve regional cooperation to realize efficient traceability throughout the industry chain.

Thirdly, a transparent and accountable traceability management system should be established to define the obligations and responsibilities of participants in the traceability system. A transparent and responsible safety management system is a prerequisite for efficiently implementing traceability system construction in developed countries such as the United States and Japan. Therefore, China must regulate and control critical links, such as agricultural product processing and production, market access, and market management, to achieve industry chain coordination and horizontal management. Specifically, timely detection and information updates on problem product recalls and related responsible entities should be carried out, reducing industry and national (regional) risks. Timely registration and regular assessments of relevant enterprises involved in essential agricultural products such as meat should also be conducted to establish an efficient and transparent system coordination mechanism.

Fourthly, an efficient traceability system should be cultivated to enhance consumer trust in food safety. International consumers' willingness to pay directly determines the actual demand for products. As the ultimate bearers of traceability system construction, their willingness to pay for traceable agricultural products determines whether enterprises can profitably implement traceability systems. Similarly, consumers' cognitive differences regarding traceability systems for meat and other agricultural products undoubtedly affect meat trade volumes significantly. Therefore, cultivating a safe and traceable international market environment requires joint efforts from governments, industry associations, and meat manufacturers, utilizing both new and traditional media to promote market and domestic consumer awareness of traceable standards. Thus, to provide high-quality and healthy meat agricultural products to domestic consumers, China needs to focus on creating a high-quality business environment to facilitate the smooth implementation of traceability systems.

Lastly, the strategic importance of traceability system construction should be elevated to prevent significant public health risks. As a major importer and exporter of meat products, China must elevate the construction of its agricultural product traceability system to a national strategic level. Due to limited self-regulation capabilities in the meat industry and market, China should improve legislation at various stages of traceability system access and implementation, vigorously promote traceability systems for meat products, strengthen the international sharing of traceable meat product information, promote technological progress, and management innovation in domestic traceability systems, and guard against significant nationwide meat food safety risks.

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