



The Food Safety Level in the European Union Underpinned by the Performance of the Private Companies

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Abstract

Background: Monitoring food safety in the supply chain has been a priority of European consumer protection policies. In this context, over the last two decades, there has been a significant increase in notifications to the RASFF by private companies. **Objectives:** This study provides new insights by demonstrating that implementing private standards, such as GlobalGAP, is associated not only with increased notifications but also with reduced food safety issues when certifications are widespread. **Approach:** Thus, the effect of improvements in companies' actions, specifically the concrete application of the Global GAP protocol, on the number of notifications reported to the RASFF has been quantified through a multivariate panel-data analysis across 18 European countries. **Results:** The results highlight that while private standards improve detection, they also reduce risks, and that producer, trading company, and retail business management is indeed highly relevant to the effectiveness of the RASFF, as well as the fact that enterprises have become a leading actor in maintaining food safety. **Conclusions:** These findings underscore the importance of integrating private initiatives into public food safety policies. Specifically, the European Administration should incentivize the adoption of certification and enhance public-private collaboration to maximize food safety outcomes.

Keywords: Food safety improvement; global GAP; RASFF; private schemes; quality control innovation.

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Introduction

Between 1979 and 2021, the European Union (EU) received 80,650 health alerts regarding food products that posed risks to human and animal health. To protect European consumers' food safety, the European Commission established the Rapid Alert System for Food and Feed (RASFF) in 1979. The RASFF aims to share information among Member States on the detection of potentially harmful food products through official inspections and analyses conducted in both domestic markets and at borders. Currently, the RASFF not only allows for information exchange between the European Commission and Member States but also with non-EU countries associated with the system. The ultimate goal is to undertake preventive or reactive measures to address imminent risks. Moreover, the RASFF provides a wealth of compiled information through its public web portal (European Commission, 2022), thereby effectively reducing health alerts through retailers' self-regulation (Schaefer et al., 2018).

More specifically, RASFF notifications may primarily originate from inspections conducted by Member States at Border Inspection Posts or, when the product is already in circulation in the domestic market, from private operators within the supply chain, end consumers, or the media.

As for the sector itself, in recent decades, actions by private companies to improve consumer health protection have primarily been driven by the progressive creation, development, and enforcement of their own food safety standards on suppliers (Willems et al., 2005; Lee, 2005; Havinga, 2006; Grazia and Hammoudi, 2012, among others).

This type of private advancement in food safety has clearly gone beyond mere compliance with current legislation (Bailey & Garforth, 2014; Codron et al., 2014). Schaefer et al. (2018) highlight the retailer's role in controlling the entry of potentially harmful products. Codron et al. (2005), in their study on the interaction between decisions made by competent food safety authorities and private companies, observed how supermarket chains were increasingly committed to agricultural production conditions, tending to recognize the usefulness of private quality standards for consumers. Among the standards with the most significant implementation in European distribution channels are the BRC seal, promoted by retailers of the British Retail Consortium, the International Features Standards (IFS) protocol promoted by a group of founding retailers of the Global Food Safety Initiative, the German QS seal, and notably, the GlobalGAP (Good Agricultural Practices) certification developed by British and European supermarkets that formalized the Euro Retailer Produce Working Group. The latter certification has become the most prominent in terms of the volume of certified products, the number of certified producers, and the number of distribution channel operators who have become full-fledged members of this regulatory entity (Flachsbarth et al., 2020). Despite numerous studies in this area, the impact of private companies' actions to strengthen food safety in the EU has not been thoroughly analysed to date.

Therefore, in recent decades, the European food safety system has increasingly relied on both public regulations and private certification schemes, such as GlobalGAP, to safeguard consumer health.

Thus, while numerous studies have examined the impact of these systems individually (Nardi et al., 2020; Luo et al., 2022; Piglowski & Śmiechowska, 2024), there is limited empirical evidence on how the interplay between private certifications and the frequency of health alerts shapes food safety outcomes.

Moreover, despite numerous studies on the role of private standards in food safety (Willems et al., 2005; Havinga, 2006; Codron et al., 2014), research on their specific quantitative impact on notifications to the RASFF system remains limited. Moreover,

the current literature has not thoroughly addressed how the implementation of the GlobalGAP protocol affects the number and nature of reported alerts, nor has it explored how these private certifications interact with macroeconomic factors to influence the effectiveness of the food safety control system within the European Union.

In this context, the present study seeks to fill these gaps by analysing, using panel data, the relationship between GlobalGAP certification and RASFF notifications, thereby providing a deeper understanding of the dynamics between private regulation and public food safety.

More specifically, focusing, on the one hand, on if a higher application of GlobalGAP leads to an increased number of alerts notified to the RASFF, and, on the other hand, on if a bigger quantity of certified products contributes to a reduction in health alerts reported to the RASFF, this work not only provides an analysis of agri-food companies' role in the health notifications issued in RASFF but also a study of the influence of private quality protocols, such as GlobalGAP, and other macroeconomic variables on the effectiveness of food safety control in EU countries. For this purpose, information on macroeconomic indicators from 18 EU Member States was considered, including population and intra-community trade, variables related to the level of GlobalGAP protocol implementation, such as the number of certified products, the number of distribution channel operators, members of their regulatory entity, and the volume of notifications made by private companies to RASFF. Using panel data regression, the results show a significant relationship and influence of GlobalGAP certification in companies, explaining why they are increasingly important in protecting food safety in the EU.

Thus, this research contributes to the literature and to policy debates on how to manage food safety policy by emphasizing the importance of the origin of information on potential threats. At the same time, the role of all members of the distribution channel subject to private quality protocols is highlighted as key decision-makers, and their motivation to continuously reinforce their preventive and reactive measures to protect market food safety and themselves from legal responsibility is highlighted. In this manner, to the extent that private companies have an incentive to assume de facto self-regulation, governments' strategies have a solid foundation on which to optimize their results across the European Union.

The rest of the paper is structured as follows. Firstly, the background of this study is presented from three distinct yet simultaneous perspectives: the EU regulatory framework on food safety, the RASFF alert system, and the private certification protocol GlobalGAP. Subsequently, the methodology is presented, and an empirical analysis is conducted on the influence of these private certifications and other variables on European health control. Finally, the conclusions and political implications are presented.

Background

European food safety regulation

Following a series of food crises in the early 2000s (e.g., the bovine spongiform encephalopathy outbreak in the UK and the dioxin case), European food safety policy underwent substantial reform. Following this reform, European legislation consisted of a complex, integrated system of regulations for the protection of human and animal health covering the entire supply chain, including plant protection, processing, storage, production, import, export, and retail food sales.

In 2002, Regulation EC 178/2002 of the European Parliament and the Council of 18 January introduced the requirements to comply with what it called the "precautionary principle" for all operators in the supply chain. Furthermore, in the case of this Regulation, it served not only as the framework for the development of the RASFF but also for the creation of the European Food Safety Authority (EFSA), which would be responsible from that moment for managing and providing information on risks from the food chain.

Since 2002, only minor regulatory changes and adaptations have taken place. These include Hygiene of Foodstuffs in 2004, Food contamination in 2019, Food Labeling in 2016, Animal and Plant Health in 2013 and 2016, Legislation on animal feed and feed labeling in 2019, and Novel Foods in 2018.

Furthermore, Article 17 of the aforementioned Regulation EC 178/2002, regarding the responsibility of market operators, established that:

- Food business operators and feed business operators shall ensure, at all stages of production, processing, and distribution within the businesses under their control, that food or feed satisfies the relevant requirements of food law for their activities and verify that such requirements are met.
- Member States shall ensure compliance with food law and shall check and verify that food business operators and feed business operators comply with the relevant requirements of food law at all stages of production, processing, and distribution.
- To this end, they shall maintain a system of official controls and carry out other appropriate activities, including providing the public with information on the safety and risks of food and feed, monitoring the safety of food and feed, and other control activities covering all stages of production, processing, and distribution.
- Member States shall also regulate the measures and sanctions applicable to infringements of food law and feed law. These measures and sanctions shall be effective, proportionate, and dissuasive.

Based on the aforementioned European regulatory content, it can be seen that a regulatory turning point occurred in 2002, which assigned greater responsibility to private operators, thereby incentivizing their performance in food safety.

The RASFF Notification System

The RASFF network currently comprises the 27 EU Member States, the European Commission, the EFSA, the European Free Trade Association (EFTA: Iceland, Liechtenstein, Norway, and Switzerland), and over 60 countries worldwide. They all have access to the restricted database of the official RASFF public portal (RASFF WINDOW) on the internet.

Most of the notifications that become part of the RASFF system originate from official inspections at both the EU border and within the European market, as well as, in some cases, from the country of origin of the product before being imported into the EU, or from the World Health Organization through the International Food Safety Authorities Network (INFOSAN) (European Commission, 2021). However, in many cases, notifications do not come from official services, but from private companies that comprise the food distribution channel, which collect information through their own product analyses and controls. Nevertheless, in these latter cases, the country's relevant authority will always conduct a second test to verify the accuracy and truthfulness of the information provided by the operator upon notification.

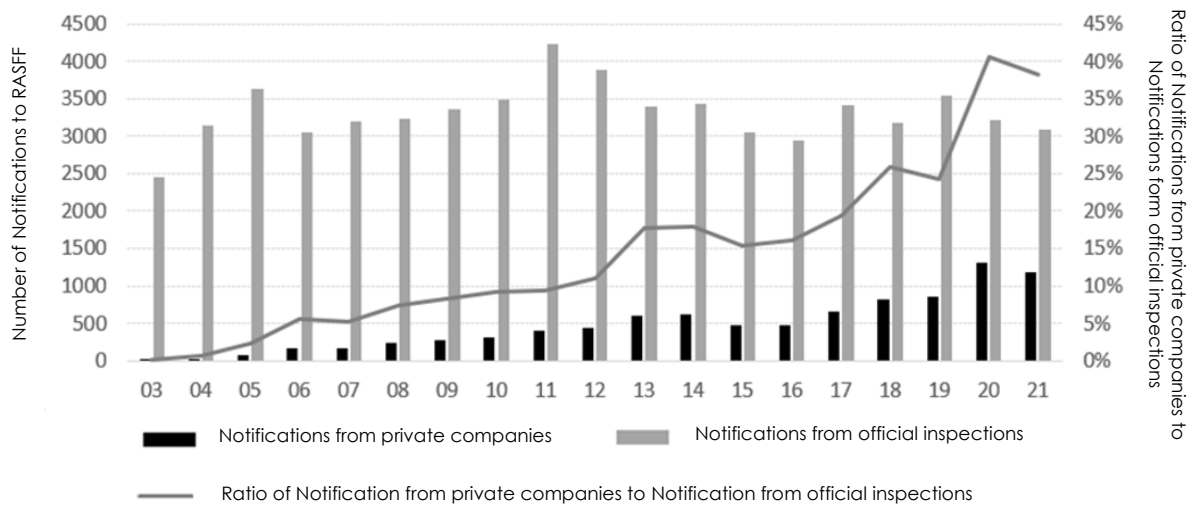
Once the notification has been created in the Member State, the competent authorities transfer it to the national unified coordination service, which then forwards

it to the European Commission. The Commission will validate and communicate this alert to the other Member States and third countries involved. Subsequently, the Commission adds the notification to the RASFF database on the internet portal.

In 2003 (with only 3 cases), the RASFF started publishing notifications of health risks reported by private companies. The trend in the number of these notifications has not stopped increasing over the past 20 years, both in absolute numbers and as a percentage of those issued by the Administrations of the Member States at the border and in the domestic market (see Figure 1). This clearly highlights, on the one hand, the need perceived by the European Administration to involve private companies in efforts to reinforce the food safety of European consumers, and, on the other hand, that companies have been carrying out this effort with increasing intensity.

Figure 1

Evolution of Notifications Originating from Private Companies and from Official Inspections since 2003 and the Ratio Between Them



Source: RASFF and own elaboration (2022)

Although RASFF did not communicate data on the origin of notifications prior to 2003, Figure 1 shows that the number of notifications made by companies increased from 3 in 2003 to 1,179 in 2021, while the number of notifications made by the Administration ranged from 2444 in 2003 to 3086 in 2021 over the same 18 years, peaking at 4238 in 2011. Moreover, the increased relevance of company activity meant that it accounted for 40.54% of notifications from official sources in 2020, up from 0.13% in 2003, representing 26.40% of the total (companies, Administration, final consumers, cases of intoxication, and media). The difference between the two trends has led to a pronounced, almost uninterrupted increase in the relevance of private activity relative to public activity. Thus, the effectiveness of this European food safety protection system has increasingly depended on the performance of private companies.

The GlobalGAP certification

This scheme, initially called EurepGap, was created in 1997 by retailers that comprised the Euro-Retail Produce Working Group (EUREP). The main objective was to harmonise the various food safety, environmental protection, and health and safety standards developed and applied by the different members.

In March 2001, the EuroHandelsinstitut e.V. (EHI), or European Trade Institute, which had managed the EurepGAP protocol until then, founded the independent subsidiary

company 'FoodPLUS GmbH', which would thereafter be responsible for implementing and developing the protocol. At that time, the market for EurepGap-certified products consisted of the 22 retailers associated with EUREP; however, certification did not guarantee that a product would be included in their supermarkets, although it was already becoming clear that this could become a prerequisite in the future.

In 2002, some fruit and vegetable retailers already publicly stated their intention to require EurepGap certification from all their suppliers starting in January 2003. Later, in the spring of 2003, EurepGAP, through its official website, announced that some retailers associated with the protocol were already requiring all their suppliers to be EurepGAP certified by 2004. Other retailers, who had not yet set a deadline at that time, would soon reconsider having commercial relationships with suppliers who were also not certified in EurepGAP (Dankers & Pascal, 2004).

In 2007, the EurepGAP protocol was renamed GlobalGAP.

Since its creation, the main objective of this protocol has been to develop a Good Agricultural Practices (GAP) standard adaptable to the wide range of conventional agricultural products worldwide. Its certificate is designed to encompass the product's life cycle, from the pre-production phase (its inputs) to its provision to end consumers by retailers (Fuchs & Kalfagianni, 2010).

The members that comprise GlobalGAP are retailers (supermarket chains), intermediate channel operators, and certifying companies. In the production phase, the latter are responsible for verifying each producer's compliance with the protocol for each product. This compliance involves carrying out activities and measurements, such as analyzing residues and contaminants during the production process, and ensuring the results are reflected in the tracking documentation to support the audit.

Therefore, farmers must conduct several analyses of their products within the range allowed by the GlobalGAP protocol to which they are subject (Wysokiński et al., 2012). Suppose any of these analyses indicate that a product exceeds the protocol's suitability limits or the legal limits. In that case, the penalty for the producer placing that product in the supply chain is so severe that it encourages growers to avoid it (Willems & Roth, 2005). This penalty would constitute both a market and, given the responsibility assigned to producers by the aforementioned European legislation, a legal risk.

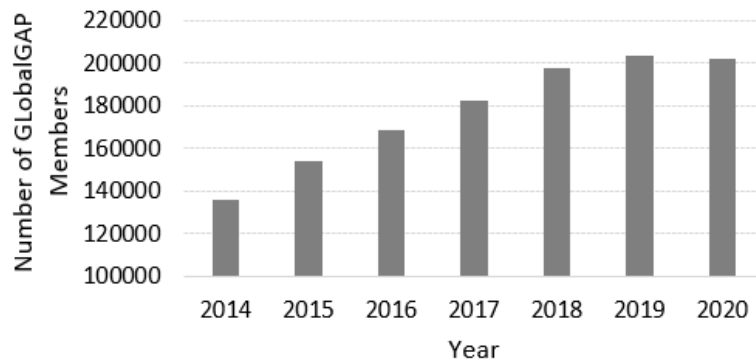
Other channel operators, such as members of GlobalGAP, also conduct inspections to verify that their suppliers comply with the protocol. This practice not only ensures they cover their legal responsibility and market risk (Wilcock et al., 2011; Rouvière & Latouche, 2014) but it also bolsters the effectiveness of their marketing strategy (Sun & Wang, 2019; Stranieri et al., 2016; Samoggia et al., 2019).

The growth, development, and expansion of this protocol over the last 20 years have made it a predominant actor in the framework of international standards covering health, social, and environmental aspects in Europe. Consequently, it has been widely adopted among large European supermarket chains (European Parliament-Agro Committee, 2022).

Therefore, a context emerged in 2002, with incipient impulses and motivations in both the private and public sectors to pursue health-safety controls on fruits and vegetables in Europe that had not existed previously. Considering this context, it seems plausible to suggest that private companies began issuing alerts due to both the entry into force of Regulation EC 178/2002, as noted by Postolache et al. (2020), and commercial pressure to implement EurepGAP (Figure 2). Following the initial impact of these two factors in 2003, it is noteworthy that over the following 20 years, while regulations were hardly updated, the number of certified producers and members of the GlobalGAP protocol increased substantially (Flachsbarth et al., 2020).

Figure 2

Evolution of the Number of GlobalGAP Certified Fruit and Vegetable Producers



Source: GlobalGAP Annual Report 2020.

Having explored the background of the subject, the authors propose the following research objectives. This work aims to determine, first, whether the greater application of private standards, in this case GlobalGAP, in companies along the commercial channel results in more alerts notified to RASFF, and second, whether extending these certifications to more products reduces health alerts.

It is important to note that these two questions, together, encompass all operators in the distribution channel, from start to finish. On the one hand, certificates are granted to producers who operate as channel suppliers of controlled products. On the other hand, GlobalGAP members are also operators who demand, from the production phase onwards, controlled products and test them.

Therefore, both those responsible for placing products on the market under said protocol (with the series of food safety analyses required) and those responsible for demanding GlobalGAP products and subjecting them to analysis under their corresponding operator protocol guidelines are considered in this research.

Hypotheses and background

Based on the context described and the objectives of the study, it is expected to address two primary research questions:

- Does the higher application of private standards, specifically GlobalGAP, by companies in the food distribution channel lead to an increased number of alerts notified to the RASFF?
- Does the extension of GlobalGAP certifications to a broader range of products contribute to a reduction in health alerts reported to the RASFF?

According to these questions, the following hypotheses were proposed:

- H1: The greater the number of GlobalGAP members in the distribution channel (excluding producers), the higher the likelihood of alerts being reported to the RASFF due to enhanced monitoring and quality assurance practices.

In this regard, Pięłowski and Śmiechowska (2024) highlight how private certification schemes such as GlobalGAP contribute to improved reporting accuracy and a higher volume of RASFF notifications. Similarly, the uneven adoption of GlobalGAP across regions has a direct impact on the effectiveness of monitoring systems like the RASFF, emphasizing the role of structured frameworks in hazard identification and reporting (Flachsbarth et al., 2020) as well as fostering improvements in risk detection processes, particularly in international trade contexts (Naiki, 2014).

- H2: An increase in the range of products certified under GlobalGAP is associated with a reduction in health alerts, reflecting the protocol's effectiveness in mitigating risks during production.

The widespread adoption of GlobalGAP also has a preventive effect, reducing the risk of food safety incidents. Previous studies indicate that enforcing standards focused on training, infrastructure, and systematic risk assessments reduces the frequency and severity of safety breaches (Machado Nardi et al., 2020; Hussain et al., 2024). This effect is particularly evident in countries with supportive regulatory frameworks and market structures that incentivize compliance. Additionally, the integration of advanced traceability technologies, such as those endorsed by EU policies, further enhances the capability to preventively address potential hazards (Pettoello-Mantovani & Olivieri, 2022).

Thus, taking as a ground for these hypotheses the assumption that private standards play a pivotal role in improving food safety by incentivizing companies to adopt rigorous self-regulation practices and, ultimately, influencing notification patterns to the RASFF, this study aims to test these relationships empirically using a panel data regression model.

Methodology

Dataset

The dataset consists of 72 observations across six dimensions for 18 EU Member States (described in Table A2 in Appendix), spanning four consecutive years (2017 – 2020). These dimensions include the number of alerts notified to RASFF by companies, the number of GlobalGAP members, the number of products certified under GlobalGAP, the total trade between the countries considered for the study, the population of these countries, and their GDP. The years range from 2017 to 2020. The dataset represents 89.16% of all notifications originating from private companies during the study period.

For the analysis, all EU countries where each GlobalGAP member has a presence and influence and can therefore generate notifications to RASFF were considered. These members include supermarket chains, origin brokers, destination wholesalers, and other supply chain operators. The data collected in the variable were gathered from the GlobalGAP Annual Reports. The data on the number of products certified by GlobalGAP were taken from both the GlobalGAP Annual Reports and the organization's institutional website, reflecting the total number of products subject to this protocol, regardless of whether they are grown by the same or different farmers. The values for intra-EU imports were extracted from INTRASTAT and include the 21 TARIC codes listed in Table A1 (Appendix), which correspond to all foodstuffs for human and animal consumption, as considered by RASFF. Population data were taken from EUROSTAT. GDP data for the 18 countries from 2017 to 2020 were obtained from the World Bank.

Research model

To conduct a quantitative analysis and answer the two posed questions, a panel regression analysis was performed on balanced panel data.

The analysis employed a fixed-effects panel data model, justified by the data's characteristics, including heterogeneity across the analysed countries and the need to control for unobservable variables that might influence the number of notifications to the RASFF. This model was selected after conducting specific tests, including the

robust Hausman test, which confirmed that the fixed-effects model provided consistent estimates.

Additionally, to address potential heteroscedasticity and cross-sectional dependence, the Driscoll-Kraay robust method was implemented in the estimation, which, as a standard errors approach, helps reinforce the use of a fixed-effects model in contexts with small numbers of observations (Tobechukwu & Azubuike, 2020; Hoechle, 2007).

Finally, to ensure unbiased and precise estimators even in the presence of cross-sectional and temporal dependence among the observation units, a robustness analysis was conducted using different model specifications, including OLS, GMM, and additional regressions incorporating alternative control variables. In all specifications, the key coefficients maintained their direction and significance, reinforcing the validity of the conclusions.

Thus, in an attempt to explain the influence of the private quality protocol GlobalGAP on the number of notifications by companies in the RASFF, the following model was generated:

$$Y_{it} = f(rs_gap_{it}, cert_gap_{it}, import_eu_{it}, gdp_capita_{it}, population_{it}) \quad (1)$$

where $i = 1$ to 18, corresponding to the country of analysis; and $t = 1$ to 4, corresponding to the period 2017-2020.

The general form of the model estimated in this study is as follows:

$$Y_{it} = \beta_0 + \beta_1 X1_{it} + \beta_2 X2_{it} + \dots + \beta_k Xk_{it} + \alpha_i + \epsilon_{it} \quad (2)$$

Where:

- Y_{it} represents the dependent variable, specifically the number of alerts reported by companies to the RASFF, for country i at time t .
- $X1_{it}, X2_{it}, \dots, Xk_{it}$ are the explanatory variables, including the number of GlobalGAP certifications, GlobalGAP members, intra-community imports, population size, and GDP per capita, among others.
- $\beta_1, \beta_2, \dots, \beta_k$ are the coefficients to be estimated, representing the effect of each explanatory variable on the dependent variable.
- α_i captures unobservable country-specific effects that remain constant over time.
- ϵ_{it} is the idiosyncratic error term, assumed to be independent and identically distributed.

As a dependent variable, it has been used:

- Number of notifications made by companies to RASFF. Within the model, the variable *aler_comp* expresses the number of notifications published in RASFF originating from private companies. The behaviour of this factor has been studied as an independent variable by De Leo et al. (2021) to explain notifications related to materials in contact with food, and by Caldeira et al. (2021) in relation to notifications involving Anisakis cases, among others. Furthermore, regarding a possible system flaw, Petroczi et al. (2011) propose that some company notifications may have been registered as originating from official inspections. However, this work offers a novel approach to studying alerts originating from private companies as a dependent variable.

The explanatory and control variables considered in the study are listed below:

- GlobalGAP members. The *rs_gap* variable records the number of retailers and channel operators (excluding producers) that require their suppliers to comply with the protocol.
- GlobalGAP certifications. The *cert_gap* variable represents the total number of certificates (in thousands) given by the product to each producer. In other terms, the same producer may have different certificates for different products.

- Intra-EU imports. With the intention of measuring trade among the Member States and as a proxy for the volume of import operations, `import_eu` (in thousands of Tons) collects the quantity of imports from other Member States for the countries studied. Other works, such as that of Postolache et al. (2021), show the positive influence of the scale of intra-community trade on the number of notifications by the Member States to the RASFF.
- Population. The population variable includes the population of each country in the study for the 4 years analysed. The population has previously been addressed by Taylor et al. (2013), who demonstrate a positive correlation between population and the total number of RASFF alerts. However, they find differences across Member States.
- The variable `gdp_capita` represents the per capita GDP (in Euro) and is used as a proxy variable for the quality of the consumed food. While the relationship between GDP and trade subject to private quality standards towards the EU has been studied in previous works (Taghouti et al., 2015; Jongwanich, 2009; Baylis et al., 2011), showing a positive correlation, this variable has not been considered from the importer's perspective, which is the relevant one to the present study. This aspect is significant because the companies of EU member states (importers in international trade to the EU) are the source of the notifications studied in this work, and thus, it can serve as an important control variable to account for each country's economic situation in the model.

Results

Table 1 provides a detailed description of the variables used in the study, including their descriptive statistics. Six key variables are presented: the number of alerts reported by companies to the RASFF, the number of GlobalGAP members, the number of GlobalGAP certifications, intra-community imports, GDP per capita, and population. These variables cover data from 18 EU Member States over four years. The mean, standard deviation, minimum, and maximum values reveal substantial variability across the variables, highlighting disparities between countries in population size, economic activity, and intra-community trade volume. For instance, the number of alerts reported ranges from 0 to 234, underscoring the heterogeneity in companies' engagement with the RASFF system. These statistics emphasise the importance of analysing each country's specific dynamics to understand the impact of factors such as the adoption of private certifications on improving food safety across Europe.

Table 1

Descriptive statistics of the variables of the applied model

Variable	Mean	Std. dev.	Min.	Max.
<code>aler_comp</code>	43.05	57.4	0	234
<code>rs_gap</code>	11.65	10.08	3	40
<code>cert_gap</code>	12100.88	21384.11	0	88778
<code>import_eu</code>	15908.99	16768.16	1364.44	64752.59
<code>gdp_capita</code>	42021.83	24906.21	10807	116597
<code>population</code>	22382.95	24769.29	590.66	83166.71

Note: The values of the variables `import_eu` and `population` were reduced by a factor of 1000

After verifying the absence of significant correlation or multicollinearity using the variance inflation factor matrix for the explanatory and control variables of the model, as shown in Table 2, the suitability of analysing the data as a pool or a panel was tested using the Breusch-Pagan Lagrangian multiplier test. The absence of serial

correlation was confirmed by the Wooldridge test, which yielded a p -value > 0.05 , whereas the Pesaran test indicated cross-sectional dependence (p -value > 0.05). The presence or absence of heteroskedasticity was determined using the Wald Modified test, which yielded a p -value < 0.05 , confirming its presence. Once cross-sectional correlation and heteroskedasticity were confirmed in the estimates, the Hausman test was performed to determine that a fixed-effects analysis should be used. In this case, obtaining a p -value < 0.05 , a robust version of the Hausman test was used, as the ordinary Hausman test is not appropriate under these conditions. The corresponding robust test applied is documented in Wooldridge (2002). Finally, given the presence of cross-sectional correlation and heteroskedasticity, and in line with Zhang et al. (2022) and Wang et al. (2022), a Driscoll-Kraay standard errors regression was estimated.

Following Hoechle (2007), in the presence of heteroskedasticity, the standard error estimator implemented is robust to temporal and cross-sectional dependence.

Table 2

Results of the performed tests to select the model

Test	P-Value	Result
Breusch and Pagan Lagrangian	0.000 < 0.05	Analysis using panel data
Wooldridge	0.16 > 0.05	Serial correlation does not exist
Pesaran	0.0008 < 0.05	Cross-sectoral dependence exists
Wald Modified	0.000 < 0.05	Heteroskedasticity exists
Robust Hausman test	0.002 < 0.05	Fixed effects model

Source: Authors' work

As shown in Table 3, the R2 within each unit indicates that the exogenous variables explain 60.30% of the variation in the dependent variable over the study period. In other words, the application of the GlobalGAP protocol by operators across different European food distribution channels accounts for two-thirds of the variance in all alerts reported by companies to the RASFF system. Thus, the remaining 39.70% may be explained by other factors, such as the described regulations and the existence of other private certifications, such as IFS or BRC, not considered in this study.

Furthermore, a significant and positive coefficient for the variable rs_gap (p -value < 0.05) indicates that the more GlobalGAP members are placed downstream of production, the more alerts companies report to RASFF, which was the first hypothesis (H1) of the present study.

On the other hand, the significance (p -value < 0.05) and negative sign of the $cert_gap$ variable allow us to answer the second question raised in this work, affirming that the more GlobalGAP-certified products producers manage, the fewer alerts are reported to RASFF, thereby confirming the second hypothesis (H2).

Among the control variables, both $import_eu$, which measures intra-European trade, and $population$, which measures the Member State's population, both with p -values < 0.05 , show a direct relationship with the number of alerts reported to RASFF, as reported in previous studies. On the other hand, " gdp_capita " has a p -value > 0.05 and is not statistically significant in this model. However, it shows a relationship in the same direction as the alerts to RASFF, consistent with the existing literature.

Table 3
Results from the fixed-effects regression model

Variables	Coefficient
rs_gap	11.4849* (2.2796)
cert_gap	-3.6607* (1.6766)
import_eu	0.0062* (0.0016)
gdp_capita	0.113 (0.625)
population	9.33* (3.94)
constant	-358.804* (83.92)
Num. observations	72
Num. groups	18
Prob > F	0
Within R-squared	0.63

Note: Driscoll/Kraay standard errors are in parentheses; * $p < 0.05$

To assess robustness, three types of analysis were performed on the panel data model with fixed effects. As shown in Table 4, the results of treating the data as a pool using OLS are presented first. Next, the results of a GMM model are shown. The last two models correspond to fixed-effects regressions with variation in the initial explanatory variables. This robustness process has been carried out based on statistical inference from the initially obtained errors (preliminary tests in Table 2), further complemented by changes in the model variables, following methodologies such as those of Simonsohn et al. (2019) and Neumayer and Plümpner (2017), among others.

Table 4
Robustness analysis

	Pool OLS	GMM	Fixed effects MOD 2	Fixed effects MOD 3
rs_gap	1.758* (0.503)	12.6404* (1.3119)	11.3363* (2.1626)	11.5623* (2.13)
cert_gap	-0.0006* (0.0001)	-0.0024* (0.0003)	-0.0042* (0.0018)	-0.0034* (0.0015)
import_eu	0.0024* (0.0003)	-0.0045* (0.0012)	0.0068* (0.0015)	0.0064* (0.0012)
gdp_capita	0.0002* (0)	-0.0005* (0.0002)	-0.001 (0.007)	
population	0.0003* (0.0001)	0.0014* (0.0007)	-0.0119* (0.0014)	0.0095* (0.0042)
constant	-8.061* (2.569)	-279.20 (2032.2)	-429.65* (24.36)	-362.55 (0)
import_noeu			0.0028 (0.0018)	
export_eu				-0.0001 (0.001)

Note: Standard errors are in parentheses; * $p < 0.05$

Table 4 shows that the dependent variable across all models is the number of alerts reported by companies to the RASFF. The GMM regression was carried out in two stages, instrumenting all independent variables with their first lags, as described in

Grundke and Moser (2019). Models 2 and 3, having confirmed the presence of cross-sectoral dependence and heteroskedasticity, apply the same methodology as the main model. Apart from intra-European trade considered in Model 1, Model 2 also includes imports from Member States outside the European Union, that is, the total imports of the countries in the panel. Studies such as Taylor et al. (2013), which also include population volume, show a positive relationship between import volume through Member States' borders and the number of notifications made to the RASFF. Model 3, unlike the main model, includes all trade within the EU, that is, both imports and exports between Member States, which, in line with Pigloski (2021), also influence the number of notifications to the RASFF. Furthermore, this last model excludes the per capita GDP variable because it is not statistically significant in the other models with fixed effects.

Across all analyses, the direction of the effects of the dependent variable coefficients related to the issues addressed in this research (*cert_gap* and *rs_gap*) remains the same.

Policy implications

The results of this study provide policymakers with important insights to enhance food safety strategies within the European Union. One of the main conclusions is the significant role played by private companies and standards such as GlobalGAP in risk detection and prevention. This suggests that public policies could be more effective if they focus on strengthening collaboration with private actors and encouraging compliance with quality standards.

In a real-world scenario, regulators could consider offering economic and fiscal incentives to companies that adopt and maintain high-quality standards, such as tax exemptions or subsidies to cover certification implementation costs. This would not only motivate more operators to seek certification but also enhance the food safety system's monitoring capacity without requiring additional public-sector resources.

Furthermore, policymakers could collaborate with certification entities, such as GlobalGAP, to develop training and capacity-building programs to ensure that producers and other actors in the supply chain fully understand the standards and their importance. Such programs could be tailored to different levels of the supply chain – from small-scale farmers to large distributors – to improve the effectiveness and understanding of standard compliance.

Another practical implication could be improvements to communication platforms and data-sharing systems between the public sector and private companies. For instance, policymakers could promote technological integration through real-time information systems that enable faster detection and coordinated responses to risks. Such systems could facilitate alert validation and optimize notification management to the RASFF.

In terms of regulatory adjustments, lawmakers could consider updating regulations to formally recognize private certifications as integral to food safety policies. This would not replace public regulations but complement them, maximizing consumer protection through a combination of public and private standards. Additionally, these policies could establish clear criteria for collaboration and joint audits, optimizing resources and ensuring effective monitoring throughout the entire supply chain.

In this regard, it has been confirmed that operators who can transfer responsibility to the previous link in the chain report any abnormal results from their own analyses to avoid risking their image or assuming legal culpability. In this way, minimizing the negative impact on the channel leads them to supply themselves as much as possible with certified production (Hernández-Rubio, J. et al. 2018).

Likewise, being subject to GlobalGAP compliance leads producers to conduct a minimum number of analyses (as with other channel operators), thereby enabling them to detect products that will be rejected downstream in the supply chain earlier. Such goods are therefore discarded before being introduced into the channel, thus avoiding very likely business repercussions.

Hence, an explicit conclusion can be drawn regarding the importance of the performance of different types of supply chain operators in the functioning of the RASFF, the attitude that underlies that performance, and the forces that drive it.

Likewise, it is observed that the food safety protection system for European consumers has become increasingly dependent on private companies' performance over the past few decades. It is also highly relevant for policymakers to have information on the relative weights of the variables that affect the achievement of the set food safety objectives. This study provides a measure of how much responsibility agents within private activity in the EU bear for achieving these objectives. Additionally, the study explains why this performance occurs, depending on the type of operator in the food supply chain. This allows for a deeper understanding of each operator's interests and circumstances, enabling them to be considered in a differentiated and adjusted manner. To improve the system's overall performance, it is necessary to optimize each component. Increasing coordination with private agents, streamlining their operations, and incentivizing the actions they are already taking will yield significant benefits for food safety for European consumers. However, the above does not suggest an increase in public quality standards. In fact, as noted by Codron et al. (2005), it is the complementarity of public and private standards that will maximize consumer protection. This study provides relevant insights into the supply chain, helping governments understand and consider the strategies and objectives of private actors. In short, the analytical perspective presented in this study provides governments with a decision framework on private quality standards.

Conclusion

Considering that notifications reported by companies began to be published in 2003, two events in 2002 had a direct effect on this type of alert. The first was the publication of Regulation EC 178/2002, which created the European Food Safety Agency and also reinforced the importance and responsibility of distribution channel operators in food safety. The second was the substantial increase in the requirement for members of the GlobalGAP (EurepGAP at that time) to comply with the protocol with their suppliers.

The main objective of this study was to verify to what extent the greater demand for certified products and, therefore, the implementation of private quality protocols in the food distribution channel, have been factors that have propelled companies to the prominence they currently hold in total notifications to RASFF.

In a context in which there was a change in the behaviour of supply chain members in recent decades regarding purchasing to reinforce brand value and consumer confidence (Schaefer, 2018), from the results of this study, it can be concluded that the prominence of companies in the RASFF is consistent with the obligation imposed by GlobalGAP to conduct analyses of the products they market, i.e., those already circulating in the distribution channel.

At the same time, one limitation of this study is the range of years covered by the data. Without a doubt, expanding the temporal scope of the data will improve the conclusions obtained. Additionally, including data on the implementation of other certificates in the dataset can further explain the correlation between the implementation of private protocols and the number of notifications to the RASFF by companies.

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Appendices

Table A1.

TARIC codes considered within the feature import_eu

TARIC Code	Nomenclature
01	LIVE ANIMALS
02	MEAT AND EDIBLE MEAT OFFAL
03	FISH AND CRUSTACEANS, MOLLUSCS AND OTHER AQUATIC INVERTEBRATES
04	DAIRY PRODUCE; BIRDS' EGGS; NATURAL HONEY; EDIBLE PRODUCTS OF ANIMAL ORIGIN, NOT ELSEWHERE SPECIFIED OR INCLUDED
0601	BULBS, ONIONS, TUBERS, TUBEROUS ROOTS, CORMS, CROWNS AND RHIZOMES, DORMANT, IN GROWTH OR IN FLOWER; CHICORY PLANTS AND ROOTS OTHER THAN ROOTS OF HEADING 12.12
07	EDIBLE VEGETABLES AND CERTAIN ROOTS AND TUBERS
08	EDIBLE FRUIT AND NUTS; PEEL OF CITRUS FRUIT OR MELONS
09	COFFEE, TEA, MATÉ AND SPICES
10	CEREALS
11	PRODUCTS OF THE MILLING INDUSTRY; MALT; STARCHES; INULIN; WHEAT GLUTEN
12	OIL SEEDS AND OLEAGINOUS FRUITS; MISCELLANEOUS GRAINS, SEEDS AND FRUIT; INDUSTRIAL OR MEDICINAL PLANTS; STRAW AND FODDER
13	LAC; GUM, RESINS AND OTHER VEGETABLE SAPS AND EXTRACTS
15	ANIMAL, VEGETABLE OR MICROBIAL FATS AND OILS AND THEIR CLEAVAGE PRODUCTS; PREPARED EDIBLE FATS; ANIMAL OR VEGETABLE WAXES
16	PREPARATIONS OF MEAT, OF FISH, OR OF CRUSTACEANS MOLLUSCS OR OTHER AQUATIC INVERTEBRATES
17	SUGARS AND SUGAR CONFECTIONERY
18	COCOA AND COCOA PREPARATIONS
19	PREPARATIONS OF CEREALS, FLOUR, STARCH OR MILK; PASTRYCOOKS' PRODUCTS
20	PREPARATIONS OF VEGETABLES, FRUIT, NUTS OR OTHER PARTS OF PLANTS
21	MISCELLANEOUS EDIBLE PREPARATIONS
22	BEVERAGES, SPIRITS AND VINEGAR
23	RESIDUES AND WASTE FROM THE FOOD INDUSTRIES; PREPARED ANIMAL FODDER

Source: Authors' work

Table A2.

List of EU Members considered in the study and mean of the model features

	alerf_ comp	rs_gap	cert_ gap	import_ eu (Tns)	gdp_capita (€)	population	import_n oeu (Tns)	export_eu (Tns)
Germany	106	34	21,873	63,119,308	46,105	82,874,982	14,061,895	18,818,7886
Hungary	2	7	2,328	4,471,578	15,912	9,779,554	577,653	14,012,765
Austria	15	8	5,263	9,048,585	196,989	8,838,743	1,246,941	8,308,686
Belgium	137	16	7,074	35,202,377	45,663	11,432,069	8,978,128	26,996,090
Denmark	49	12	610	5,937,950	60,083	5,789,701	3,555,043	6,453,559
Finland	22	5	259	2,748,951	48,516	5,514,910	485,676	968,491
France	128	11	15,055	26,312,204	39,804	67,083,473	11,433,849	43,058,540
Ireland	11	5	113	2,757,252	78,576	4,870,864	8,011,121	1,299,125
Italy	37	13	46,419	26,499,120	33,045	60,132,895	15,225,074	14,672,660
Latvia	1	3	9	3,420,545	68,907	1,928,035	792,572	5,388,952
Luxemburg	4	6	0	1,416,658	113,629	608,169	18,131	873,245
Poland	17	7	7,845	20,846,595	15,171	37,970,150	5,467,972	16,357,774
Portugal	2	5	6,236	8,091,644	22,678	10,293,282	4,774,836	6,449,967
Rumania	6	5	1,390	7,008,170	12,250	18,480,182	1,915,511	6,813,631
Eslovenia	5	5	145	2,381,610	25,170	2,078,421	1,900,341	5,604,045
Spain	9	27	86,063	19,036,118	28,774	46,864,036	23,794,399	19,472,091
Sweden	41	4	102	5,504,070	52,998	10,140,807	2,364,353	8,539,434
Netherlands	185	37	17,033	42,559,015	51,543	17,212,815	31,725,856	396,192,73

Source: Authors' work