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Traceability systems as a differentiation tool in agri-food value chains: a framework for public policies in Latin America

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Abstract

Purpose – The goal of this paper is to develop a classification of traceability systems that will help academics and policymakers think of them as a tool for differentiation in agri-food value chains.

Design/methodology/approach – Based on the analysis of case studies and a literature review, the authors develop a conceptual framework to classify traceability systems based on two dimensions: their scope in the value chain (individual vs integrated) and the type of information they contain (basic vs advanced).

Findings – Integrated traceability systems provide a variety of benefits vis-à-vis individual systems as a tool to achieve greater product differentiation by meeting current and latent requirements from foreign countries' governments and consumers. Also they serve as a platform for including advanced (vis-à-vis basic) information into the system.

Research limitations/implications – A series of studies would be required to quantify the relative costs of different traceability systems and compare them on a cost-benefit basis. Nevertheless, since integrated traceability systems are subject to coordination failures, significant public focus and efforts should be placed on the potential promotion of those systems.

Originality/value – This paper provides a novel classification of traceability systems that distinguishes them according to scope and information content.

Keywords Traceability, Agri-food value chains, Latin America

Paper type Research paper

1. Introduction

The increasing sophistication of food demand in developed countries forces Latin American producers to be able to show reliably and consistently that their products adequately address the most demanding desires, concerns and requirements of those markets. Consumers in developed nations seek to enjoy products with attributes they value, such as the safety of

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their production methods, environment-friendly practices and fair working conditions. In response, many retailers build their market positioning around their ability to guarantee that their products meet these new and changing demands. In turn, governments enforce an increasing number of mandatory requirements to guarantee safety standards and to protect their countries' crops and cattle from the effects of plagues and diseases (World Bank, 2005; OECD, 2007).

Against this backdrop, traceability systems are key tools to enhance the exporting performance of Latin American companies. On the one hand, they enable compliance with the frequent requirement from importing countries' healthcare officials regarding the capability to immediately withdraw any food product from the market or from any stage of the logistics process in case of sanitary, phytosanitary or human health hazards ("basic traceability"). On the other, by providing additional information to that required for product withdrawal these systems help to address the concerns and demands of consumer groups and international supermarket chains ("advanced traceability"). For instance, they can corroborate that deforestation has not taken place in the production area or that child labor has not been used in the production process. Thus, in addition to enabling a swift product recall, traceability systems are an effective tool to showcase a variety of valued attributes as differentiating traits. As a result, they can quickly respond to new demands and requirements and are becoming increasingly necessary to preserve companies' and countries' presence in high value-added markets (Aung and Chang, 2014; Opara, 2013; Routroy and Behera, 2017).

Exporting companies often have their own traceability systems ("individual systems"). An individual system is typically run by a single company, which is the only information provider (even if the data entered includes information affecting other stakeholders, such as suppliers or clients). Alternatively, traceability can be achieved by means of a single integrated system for the value chain ("integrated chain systems" or, for brevity, "integrated systems"), with harmonized information requirements for all participating companies. Integrated systems offer considerable benefits in terms of efficiency, scale, normalization, information usage and reputation as compared to individual systems. Thus, they can provide an effective response to the demands of public regulators and private clients in importing countries. Also, they can serve as a platform to build advanced traceability systems that meet clients' growing information requirements.

Developing an integrated traceability system poses significant challenges as it is subject to coordination failures and thus may not arise as the natural outcome of market forces. Specifically, it requires the leading role of a coordinator, whose natural candidate is the relevant regulatory agency – such as the national service of agri-food health and quality (henceforth, "sanitary authority"). Among several challenging tasks, the system coordinator must align every chain participant under shared objectives and coordinate the efforts of public sector agencies engaged in the system's development and monitoring. In the case of systems that contain advanced information, the coordinator must also identify and build the information sets valued by clients, so as to achieve greater differentiation. In Latin America, companies largely devise their own individual systems, which are audited by sanitary authorities as part of their process of issuing export certificates. In contrast, there are just a few integrated traceability systems in place.

The main goal of this study is to build a classification of traceability systems that we think proves useful from a public policy perspective to identify public policy needs to make these systems effective tools to promote the internationalization of agri-food chains via product differentiation. Our classification is based on two variables: system scope (individual or integrated) and information content (basic or advanced). Based on this classification, we highlight the advantages offered by integrated systems – more so when they include advanced information – but also describe the challenges involved in their development and implementation given their strong demand for coordination. As a result of our analysis, we recommend a strong public focus on the analysis and, when deemed beneficial, promotion of this type of (underdeveloped) traceability systems. Finally, we illustrate the involved benefits and challenges of integrated traceability systems with the development and implementation experiences of two of the few integrated traceability systems in place in the region – namely, Argentina's Integrated Citrus Traceability System (SITC, for its Spanish acronym), an integrated basic system designed by Argentina's National Service for Agri-Food Health and Quality (SENASA), and Uruguay's National Cattle Information System (SNIG), an integrated advanced system devised by Uruguay's National Meat Institute (INAC).

The academic literature has dealt with traceability systems from several angles. However, it has barely focused on integrated systems, on the role of public policies in promoting their development, or on the relative benefits and costs of this type of systems vis-à-vis individual ones. A first body of work focuses on operating problems associated with the implementation of individual traceability systems. For example, Dabbene *et al.* (2014) and Scholten *et al.* (2016) discuss a number of technological and information schemes that companies can adopt to develop their traceability systems while Gupta and Kaul (2017) review a bulk of studies that deals with those issues. More recently, a considerable number of studies have focused on the possibilities brought about by the emergence of blockchain technologies (Garaus and Treiblmaier, 2021; Behnke and Janssen, 2020; Casino *et al.*, 2019).

A second body of literature shows the benefits that companies draw from traceability systems. Cho and Choi (2019), Yin *et al.* (2017), Hou *et al.* (2020), Jin and Zhou (2014) and Liu *et al.* (2019), among others, have explored consumers' willingness to pay premium prices in several markets for agri-food products supported by these systems. In turn, Stranieri *et al.* (2016) analyze the incentives offered to firms for voluntarily adopting traceability systems. All these studies deal with individual traceability systems without reference to the potential use of integrated systems across the value chain. An exception is Shanahan *et al.* (2009), who underscore the benefits afforded to consumers when they can count on an integrated traceability system as the one used for cattle in Ireland. Yet, this study does not approach the development of this type of systems from a public policy standpoint.

International agencies working on agri-food and farming issues have approached traceability from a policymaking standpoint. However, their approach has also focused on individual systems. The UN's Food and Agriculture Organization (FAO), for instance, created a manual with guidelines for the construction of (individual) traceability systems (FAO, 2017). Also, jointly with the World Health Organization, FAO has elaborated a guide for the development and improvement of national systems for food product recalls (FAO/WHO, 2012). While a significant share of their recommendations is oriented to the regulatory, procedural and operating steps that public officials should take, these recommendations implicitly assume that public officials responsible for guaranteeing traceability exchange information with actors that have their own individual traceability systems in place. In turn, the Inter-American Institute for Cooperation in Agriculture (Green, 2007) describes cattle traceability systems in place in several countries, showing how private and public systems interact. Nonetheless, like Shanahan *et al.* (2009), this study does not analyze the benefits provided by integrated chain systems or discuss the public policy challenges inherent to their development.

We hope the new classification of traceability systems we propose here will help to organize the public discussion on traceability as a differentiation tool for agri-food exports – a discussion that we deem has not been sufficiently fruitful so far as a consequence of the lack of a clear conceptualization of those systems. In this regard, we expect that our classification will facilitate the identification and analysis of public policy alternatives that will eventually guide the design and implementation of effective traceability systems to encourage the differentiation of Latin American agri-food exports.

2. Methodology

This study builds a novel typology to classify Latin America's food traceability systems, which we believe will prove useful to formulate public policies to promote the internationalization of agri-food chains via product differentiation. This typology was devised on the basis of the analysis of traceability systems documented in the academic and public policy literatures, as well as those identified across the various studies conducted within the Inter-American Development Bank's Private and Public Strategies for Success in Agri-Food Markets project. The traceability solutions – involving systems deployed by sanitary or regulatory agencies as well as by private sector players – found in Latin America as part of our own research were also taken into account. This information enabled us to identify the two major dimensions that characterize traceability systems: (1) system scope (individual or integrated) and (2) information content (basic or advanced).

For this research study, we conducted 32 interviews – 12 with people associated with public agencies such as the sanitary authority and public agricultural and industrial technology services, 12 with agri-food companies and business associations and 8 with companies that develop IT traceability solutions. In the first case, we interviewed the heads of traceability systems deployed by regulatory agencies or organizations overseeing agri-food issues in Argentina, Uruguay, Peru and Costa Rica – all countries where significant progress has been made in the development of traceability systems. In the second case, we interviewed company managers and officials from business associations – some of them managers of their own firms – that are developing or have developed their own traceability systems. In the third case, among companies that develop IT traceability solutions we reached out to the technology companies in charge of the technological solutions underpinning the two integrated traceability systems in the region that are used as examples in this study as well as people from a number of companies that are currently offering traceability software solutions in Latin America's market to individual producers – all of these firms serve clients that export their products.

Additionally, in collaboration with other researchers that participated in the aforementioned IDB project, we also surveyed relevant information about the traceability systems appearing in the studies carried out as part of that project, which has encompassed this research study as well. We also reviewed the websites of the sanitary authorities of various countries in Latin America, as well as those of international agencies such as FAO and regional organizations like IICA, which can advise on traceability system development and adoption.

All the interviews performed for the study were conducted remotely between March 2020 and February 2021. The interviews were semi-structured. This choice was guided by the need to maintain flexibility to dig deeper into unforeseen themes in our search for the relevant dimensions of our traceability system classification. The process of gathering information and building the relevant dimensions of our classification was performed in a circular fashion – following a process of mutual validation in successive interviews. The two axes of our classification were specifically discussed and validated with experts in the subject. All the interviews were recorded and the transcript and recordings are available for further analysis.

3. Existing and latent traceability demands

Some companies in developed countries have used food traceability systems since before they were mandatory. However, after severe incidents compromised public health or after diseases and plagues broke out and spread, the governments of affected countries, especially in the European Union (EU), made traceability systems compulsory for agri-food value chains. The need to deploy these systems has become even more apparent as these value chains grew more complex including increasing participants around the world.

For agricultural products, the demand for traceability is regulated by health and sanitary authorities. Traceability is typically included among the mandatory technical requirements – such as phytosanitary requisites, waste limitations and safety standards – established for market access in sanitary and phytosanitary protocols. The corresponding authority in the importing country demands that requirements be met, although the protocols place the certification responsibility on exporting countries.

Argentina's citrus exports to the EU provide an example that illustrates the critical role played by traceability in protocol compliance. To ensure protocol compliance, SENASA, the Argentine sanitary agency that is also responsible for export certification, must check that every control measure was followed properly (e.g. crop treatments, plague monitoring, package inspection and handling, and examinations at the port), identify the production unit and farm that is the source for every fruit box, as well as the packaging process used and how the boxes were transported to the port and shipped to the EU. Thus, if a disease requiring quarantine is found, EU officials can quickly exclude all potentially dangerous fruits, even those still in farms. Similarly, EU officials can remotely audit certification deviations to establish whether they warrant a change in the phytosanitary requirements for a specific country or whether measures should just be taken against the non-compliant company.

Over time, protocols are gradually adjusted to address new risks. Changes may prove slow, as has been the case of the inclusion of new plagues in EU's protocols for citruses. However, changes may also address the need to remedy critical issues urgently. Such has been the case of the changes introduced in 2020 to Argentina's certification process for citruses intended for the EU a few months after the discovery of citrus black spot [1].

Producers must also comply with some advanced traceability requirements, typically demanded by supermarket chains (including, for instance, how and when a product was shipped and stored or when it changed hands within the value chain) in order to become potential suppliers. Advanced demands may also come from consumer groups that want to ensure that the products they consume abide by some specific standards concerning animal welfare or environmental care.

In addition to current advanced traceability requirements, there are latent demands – for example, referring to the environmental footprint – that have yet to become mandatory requirement but whose fulfillment already serves as a differentiation attribute. Typically, latent demands emerge from market niches. Nonetheless, over time, they turn into common requirements, even among less demanding consumers and eventually become public requirements. Being able to address latent demands provides a better positioning to swiftly comply with new mandatory requirements.

4. Food traceability systems

Traceability systems enable users to track the history, attributes and location of a product in a value chain via organized, reliable and safe information records. There are several types of food traceability systems, each one with different levels of information content (basic vs advanced) as well as scope in the value chain (individual vs integrated).

Basic traceability systems are information management tools that allow for a swift and safe recall when a food product may pose a threat to consumers or the environment [2]. In case of an incident, all the products in the same batch can be identified and withdrawn from the market, as well as any other batches produced in the same manner. Ideally, a system should record every physical movement of and every treatment applied to a batch of products throughout the entire production and commercialization processes. The system requires a batch definition, and it should have the capability to accurately record every instance in which the product undergoes a transformation and changes hands [3]. The technology sophistication to capture and store information varies: a system may be manual – with field notebooks used to record practices –, semi-automatic – relying on spreadsheets –, or fully automated – with microchips implanted in animals [4].

Individual basic traceability systems are controlled, handled and managed by a single company that is the only source entering data into the system. Food exporting companies often rely on a system of this kind to satisfy traceability requirements of export markets. While the development and adoption of such a system may imply some process adjustments and investments (e.g. in technical consultants and software), this technology is readily available to all companies seeking to export their products [5]. Individual systems provide companies using them the flexibility to best meet their specific needs in terms of their management of financial and human resources, the complexity of their own operations, and the relationships with other members of the value chain. Moreover, having an individual traceability system allows the company the flexibility to upgrade it in response to new demands or opportunities at the pace and manner it finds most relevant.

When sanitary authorities work with individual systems, the existing information required to conduct a recall comes from the combination of data drawn from those individual systems with the information gathered by the authority as part of its procedures to issue export certificates. Thus, in case of a recall, the sanitary authority must complement the data available in its own information systems with data scattered around in several individual systems.

Unlike individual systems, *integrated* traceability systems make it possible to process information supplied by multiple value chain participants in one single system. A system coordinator – for example, the sanitary authority in the exporting country – leads the project and oversees its proper operation, making sure that all users provide the information required. With an integrated system, coordinators can access all the relevant data entered by every value chain participant, including information on production, packaging, logistics and distribution. In the case of a recall, the administrator may take the necessary steps without having to ask for additional information from participants in the value chain.

In integrated systems, the coordinator administers every participant's permissions to access the different pieces of information included in the system, preserving the confidentiality of individual companies' information but allowing their access to relevant summary or aggregate indicators. In principle, different forms of dialogue between integrated and individual systems are possible allowing firms to enjoy the flexibility of individual systems without the need to duplicate costs. In practice, however, integrated systems typically replace individual systems [6].

Advanced traceability systems, in turn, also contain – in addition to the data required for potential recalls – information valued by consumers that can help differentiate a product [7]. The information sets that can turn a basic system into an advanced system are multiple and may vary across markets and products, as well as over time. Some categories among those information sets include social corporate responsibility, working conditions, environmental impact and organic production (Henson and Humphrey, 2009; Mello *et al.*, 2021; Narine *et al.*, 2015). Regarding environmental impact, for instance, advanced systems for beef can corroborate that the cattle has grazed in areas that have not undergone deforestation. In turn, new precision agriculture and livestock farming technologies may prove useful to build those information sets. These technologies, for example, enable linking information automatically captured on site – such as irrigation patterns or pesticide applications – to every batch. In addition, as advanced traceability systems are largely geared towards addressing consumer concerns, ensuring accessibility by the consumer to the information included in the system is critical. Several mechanisms, including labels, or more recently QR codes, have been developed to enable consumers to access the information they want easily and quickly as part of their purchasing process.

In the case of beef production, for instance, consumers can be offered information regarding animal welfare conditions, narrowing it down to the specific cow from which a specific cut was taken and including data on the plots of land where the cow lived or its contribution to greenhouse-gas emissions. This information may prove interesting for consumers who may want to know whether the food they are eating meets their environmental, ethical or religious requirements [8]. The system developed by INAC for beef products provides an example of an integrated advanced traceability system in Latin America. To differentiate its products in the US market, INAC created the *Uruguay Natural* certifications starting from a system that only contained the information required to ensure basic traceability.

4.1 Advantages of integrated chain systems

From a public policy standpoint, integrated chain systems offer five key benefits as compared to individual systems. First, integrated systems are more effective and efficient to address recall demands. While it may be possible to track troublesome batches by accessing multiple individual systems, a recall can be carried out more swiftly and reliably with an integrated system, as all the information needed is stored in a single database.

Second, integrated systems leverage economies of scale when it comes to system development and updating. Thus, with a sufficiently large number of participating firms, exploiting scale economies should reduce the system's implementation and operation costs afforded by each company relative to the costs of implementing and maintaining an individual system [9]. Lower costs should also facilitate adoption by a larger number of companies.

Third, integrated systems standardize the information to be traced, effectively creating a common language that substantially reduces the efforts participants need to make to agree with one another. Thus, disseminating the best traceability practices proves substantially easier. In addition, value chain participants – largely companies in different links in the chain – have compatible information systems. Easy "communication" between systems may prove key to introduce system upgrades in order to handle more and better information.

Fourth, with integrated systems, an organized and complete database is built, which can prove useful for decision making as the information is sorted and catalogued with uniform criteria applied to all stages of information capture and processing. Thus, not only is information stored in the system useful for tracking all relevant events along the chain – as it was created and uploaded to that end – but also it may prove useful to define new processes or adjust existing ones if problems emerge. In turn, it may also help coordinators to spot threats or opportunities that would otherwise not be visible. This allows for the formulation of strategies for future actions and enhances the ability to detect problems, as, with several players working with the same information, there are more instances of data cross checking [10].

Finally, if the coordinator is the sanitary authority, the construction of an integrated system strengthens its credibility among its external counterparts as it enhances the authority's ability to control the established health and sanitary standards and to introduce changes in sanitary plans as needed. For buyers, a system organized by a sanitary authority is often viewed as more reliable as one developed by a single company. The "credibility" benefits of an integrated system have proven useful for SENASA and INAC in their negotiations to open new markets and to preserve market access in case of a crisis. For instance, due to SITC, SENASA managed to preserve access to the EU market amidst sanitary crises caused by citrus black spot cases while other countries with the same disease but without an integrated system were forced to withdraw from that market. Similarly, the reputation and credibility of INAC's SNIG helped avert suspicions of COVID-19 infections in Uruguayan shipments of beef to China to affect the country's exports.

In contrast to these advantages, individual systems, as noted earlier, have a clear advantage over integrated systems in terms of their flexibility to address firms' specific needs. Nevertheless, as information technologies progresses, it will be increasingly possible to embed flexibility and confidentiality into integrated systems to address those needs. In any event, a cost-benefit analysis should be conducted on a case-by-case basis to decide on the relative merits of the different traceability systems.

5. Public policies to promote integrated traceability systems

Despite presenting a number of relevant advantages, integrated traceability systems are notably rare in Latin America. We think that one of the main reasons behind the lack of prevalence of integrated systems is that developing them is subject to coordination failures that are not naturally resolved by the market. In fact, solving those coordination failures poses significant public policy challenges in terms of the ability to align a variety of public and private actors behind a common objective. Thus, we think that countries should have a proactive agenda to analyze the desirability of this kind of traceability systems and promote their development when deemed desirable from a public policy perspective. Integrated systems can help agri-food chains to comply more effectively with the increasingly stringent demands of foreign markets at lower costs. Additionally, their use as a differentiation tool would allow countries to increase their exports by anticipating latent demands [11].

Building integrated systems often requires the creation of a partnership between a coordinator that manages participating members and a firm responsible for the technological solution. The coordinator must have the ability to align private stakeholders in the system – as in the case of primary producers and processors, who often have a troublesome mutual relationship – and ensure that they comply with their commitments. Additionally, the coordinator must have a thorough understanding of the requirements imposed by foreign officials and, sometimes, of the potential opportunities for differentiation in foreign markets. The coordinator makes strategic decisions and ensures that several areas of the public sector carry out the actions expected from them. The coordinator also plays a significant role by interacting with companies or producers to convey the vision of the project so that the system is adopted and used. If the coordinator is a public agency, as in the case of the sanitary authority, it is important that there is also a private stakeholder in the chain, such as a producer association, that can serve as a counterpart for the coordinator in order to facilitate communication.

To develop and later monitor the system, the coordinator must also work with several public sector areas – e.g. local, provincial and national officials – with control responsibilities. The coordinator should also work with other State areas with purview on productive development, typically embedded in the ministries of trade, production or agriculture, which should also prioritize the promotion of traceability systems and contribute to their implementation. Similarly, export promotion agencies may also work on raising awareness among companies about the importance of traceability. It is paramount that all these public agencies understand the need to build systems that guarantee traceability and to support the coordinator in this task.

Sanitary authorities or other regulatory agencies seem to be the natural candidates to play the coordinating role in an integrated system. Typically, they already have the processes in place to identify and assess the conditions needed to support sanitary and phytosanitary safety. They can also impose the adoption of such a system on the value chain. In Argentina and Uruguay, sanitary authorities and agencies with regulatory purview such as SENASA and INAC were in charge of building the traceability system for the lemon and beef value chains, respectively.

In turn, the technological head must produce the specific technological solution for the needs of an integrated system. Typically, this solution does not just consist of an investment in an off-the-shelf software package. Rather, these systems require the ideation, development and implementation of a solution that is compatible both with existing technologies and with the productive sector's needs. Thus, the technological head must understand users' technological and infrastructure capabilities (e.g. whether their Internet access is continuous or intermittent), their processes and routines, as well as the information that the system will be able to effectively capture and share. The technological head may play a leadership role, not necessarily "subordinated" to the coordinator.

The public policies engineered for the development and maintenance of integrated traceability systems should consider a funding scheme for them. In some circumstances, producers' agreement to institute some kind of compulsory funding scheme to partially or totally cover system expenses may contribute to prevent some producers from free riding on the contributions of others. Also, it may help the public sector to commit its own resources to the development of an integrated traceability system as it would increase its trust in the private sector's commitment to the project.

The development of integrated advanced traceability systems implies an even greater challenge. First, it is convenient to have an integrated basic traceability system in place to build on, adding advanced information, as, in addition to providing a technological foundation, it also ensures the existence of validated, working protocols for entering and using data. Second, chain participants should be willing to share sensitive trade or tax-related information that is not necessarily used for a basic information system [12].

For an integrated advanced traceability system to "communicate" directly with buyers, it is necessary to identify and build the information sets they value. The private sector's first-hand knowledge of buyers' current and latent information demands makes it an irreplaceable player in the design of an advanced system. The joint efforts of the public and private sectors also prove relevant to diagnose the existing information and elaborate a roadmap showing how and when that information will be entered into the system. In some cases, the information is already available, although it is not used for traceability solutions. In other cases, it is necessary to organize the value chain in order to produce that information. It may even prove necessary to develop adequate metrics or standards to streamline quality requirements and employment methods.

Finally, public-private coordination is also important to advertise among buyers the existence and the benefits of accessing advanced information in the products they buy as well as to build customer loyalty. The information that is made available, albeit standardized and validated by local authorities, is not likely to be automatically acknowledged in destination markets if it is not part of a marketing and communication strategy that engages both public and private stakeholders [13]. Also, the government areas responsible for export promotion can work together with private stakeholders to find ways to use traceability information in new commercial platforms.

6. Developing an Integrated Basic Traceability System: Argentina's SITC for citruses

The primary function of Argentina's Integrated Citrus Traceability System (SITC, for its Spanish acronym) is to demonstrate compliance with the requirements established in phytosanitary protocols for Argentine citrus exports and to enable recalls whenever necessary. Designed in 2001 to address the requirements imposed by the EU after the market was closed as a result of several citrus black spot cases, this system combines information entered by several participants across the entire value chain throughout the production and exporting process. A labelling system associated with every single batch is maintained throughout the process and enables swift and efficient batch identification in case of phytosanitary alerts.

The SITC was developed jointly by SENASA and a company called Kyas. The company served as the technological head, but it also was the one to envision the system, improving the solution originally designed by SENASA – an information system based on simple spreadsheets. Kyas, located in Argentina's northeastern citrus producing area, initially focused on providing business management services, but it gradually shifted toward the design of individual traceability systems for fruit export cooperatives.

Kyas' experience with the operations of companies in this sector and the processes they needed to follow to export their products to the EU, as well as its foresight regarding the use of the Internet (a novel tool back then) to source information from remote users proved instrumental when the company approached SENASA in 2001 to collaborate in the development of an efficient system – eventually the SITC – to meet the new EU's requirements. Interested in the potential of this project, Kyas developed both the spreadsheets designed by SENASA and, at the same time, its own solution pro bono. The latter gradually grew in sophistication and visibility. The fact that SENASA did not have to commit to Kyas' solution from the onset actually helped the SITC to gradually gain momentum. Kyas' vision for the system began to earn the approval of SENASA's technicians, and the agency eventually realized that the company's proposal offered a better solution than its own project.

Having internalized Kyas' vision for the SITC and convinced of the benefits of an integrated system, SENASA managed to overcome a number of challenges regarding the coordination of stakeholders to implement it. SENASA's commitment to overcome those challenges was illustrated by its negotiation with the EU to secure a protocol that, while demanding, made it possible for Argentina to re-enter that market. For the proper operation of the system necessary to certify exports to the EU, SENASA had to include all the producers and packers across the country. Getting that information is not always easy in a country as large and plagued by informality as Argentina. Reflecting the system's priority and as part of its regulatory faculties, in 2001, SENASA issued a resolution mandating the enrolment of producers in a registry and developed effective monitoring mechanisms to prevent production in non-registered farms.

While SENASA had the authority to impose the use of a traceability system, it had to work hard to convince all chain stakeholders of the importance of its adoption and to secure their cooperation. Although the restrictions imposed by the EU provided strong incentives for all stakeholders to collaborate, SENASA faced some resistance from the private sector to share its information. To overcome the private sector's reluctance, SENASA first reached out to several exporters' associations. Finally, the Argentine Citrus Federation (Federcitrus) became the most effective counterpart for the agency, conveying SENASA's requirements to producers and convincing them of the need to collaborate to build a new traceability system.

Additionally, SENASA had to establish and communicate the data capturing and entering protocols for every link in the value chain, so that the system could gather the necessary information, enabling it to be managed seamlessly. The multiple sources and types of events involved in the information capturing process called for participants to make a joint standardization effort. Kyas' experience with citrus producers contributed to make a realistic assessment of companies' actual capability to provide information (either on account of the effort required to produce it or due to its trade or tax-relative sensitivity). In this regard, Kyas played an important role in shaping SENASA's data requirements, minimizing the potential risk of failure due to over-ambitious goals. Thus, to prevent the system from appearing too costly in terms of exposure, the minimum necessary amount of information to abide by the protocols was required. Kyas also provided active support to all the companies that needed help to submit the necessary information. To avoid a potential conflict of interests, Kyas stopped serving its citrus clients individually.

From the system's inception, the public and private sectors agreed that exporters would fund both the SITC development and a sizable share of the processes required to meet the protocols. Ensuring fund management transparency helped participants to view the system as reliable, even when political leadership changes unfolded – both in the public and private sectors.

A number of changes were introduced into the SITC over time, which shows that building integrated systems facilitates making the natural upgrades that result from new technological developments (like artificial intelligence or new apps) as well as quickly adapting to address new needs, such as adding several control steps to respond to EU requirements. Ever since the system was created, the EU gradually increased the number of plagues to control as part of the protocol in place. With the SITC, SENASA was able to react swiftly and make the necessary adjustments in critical times – like during the 2020 crisis. When the citrus black spot plague broke out, SENASA and the EU introduced changes into the protocol that became part of SITC's standard operations. The ability to make these changes swiftly enabled SENASA to preserve its international reputation and reliability.

7. Developing an integrated advanced traceability system: Uruguay's SNIG for beef

Uruguay's National Cattle Information System (SNIG, for its Spanish acronym) is a compulsory traceability system that includes all the cattle heads in the country, with information on animals' ownership and location changes, as well as their industrial transformations at slaughterhouses and meat-packing plants. In 2000 and 2001, Uruguay suffered a foot-and-mouth disease (FMD) outbreak that deprived the country of its former FMD free-without-vaccination status, which forced the EU to ban Uruguayan imports. Against this backdrop of damaged reputation and threatened market access, Uruguay's government and its private sector agreed on developing and implementing an electronic traceability system based on the solution that had originally served tax purposes.

The SNIG is a two-part system [14]. The first part records and tracks every animal, from their birth to their slaughterhouse entrance, using individual ID tags known as "RFID identifiers" distributed free-of-charge by INAC. Whenever an animal changes hands, this movement is automatically recorded in a traceability system specifically developed for SNIG that was conceived and developed by a technological firm that understood well every single requirement of external markets. The second part of the system records – via automatic scales set up in every meat-packing plant – the changes undergone by every piece of meat. All the information is automatically submitted to INAC's database. To fund SNIG, producers must pay USD 1 for every animal slaughtered [15].

The SNIG is an advanced system for two reasons. First, unlike most systems, which track animals on a group basis – e.g. by birth cohort – the SNIG can track each head of cattle individually, from its birth to its processing into beef cuts [16]. This possibility, together with the use of new technologies, has encouraged Uruguayan producers to offer more differentiated beef in China by allowing consumers, for example, to access through their mobile phones the information they value on the animal whose meat they are eating. Second, in addition to the information required by the EU's sanitary authorities, the SNIG provides more detailed information on animals' feeding and location throughout their lives to meet consumers' information needs [17]. New demands for more and better information are likely to prompt the introduction of new information sets in the medium run, such as those associated with deforestation or water utilization. The creation of new data and the ability to understand which existing data may add value for consumers have proven critical for the SNIG's development.

The SNIG's transformation from a basic to an advanced traceability system has hinged on two features of Uruguay's beef sector organization. On the one hand, Uruguay boasts a long tradition of respect for high quality livestock standards, based on productive methods that guarantee the best cattle farming practices and animal welfare. On the other, the sector's strong focus on internationalization has enabled industry players to share a vision that has led to system development and readiness for improvements.

In this case, the agency responsible for coordinating this advanced traceability system was not Uruguay's sanitary authority but INAC, a dedicated public-private promotion and regulatory agency for the beef sector [18]. As a result of its role and its operations over the years, INAC helped the industry to consolidate its exporting goals, provided credibility and trustworthiness to public-private interactions, and led the country's beef internationalization agenda. These assets proved useful for the development of an integrated and advanced beef traceability system. INAC's exporting vision made it possible that a problem that might have had only a tax control solution become the core of an internationalization strategy. The credibility and trust built by INAC between the private and public sectors also played a key role for consensual advancement. The SNIG's development required transparency for slaughterhouse and meat-packing operations. INAC managed to show that greater transparency would not only benefit primary producers and tax authorities but also slaughterhouses and meat-packing plants themselves. Finally, INAC is widely regarded by all public sector areas as the agency in charge of beef internationalization, and, as a result, they are willing to follow its lead on this agenda.

8. Conclusions

While sanitary authorities in destination countries do not currently demand specific traceability systems in place as long as exporting countries' sanitary authorities guarantee effective product recall in case of sanitary, phytosanitary or human safety threats, integrated traceability systems provide an increasingly valuable tool to differentiate products in food markets.

Amidst rising traceability demands, we believe that promoting the development of integrated systems can be an effective public policy response to those demands. These systems offer benefits over individual systems in terms of efficacy, economies of scale, standardization, information usage and reputation. These benefits favor international protocol negotiations, contribute to minimize negative impacts in times of crisis, prove easier to adapt to new requirements – e.g. caused by the COVID-19 outbreak – and provide a differentiation tool due to their potential for addressing increasingly demanding consumer needs.

A lingering question is to what extent basic traceability systems containing the information required by regulators can serve as the basis for advanced traceability systems, or whether the goal should be to have schemes that combine basic systems oriented to meeting sanitary authorities' demands with private advanced systems. The answer is not that clear, as the organization of advanced traceability systems requires more complex ties among system stakeholders. As shown by Uruguay's INAC, such ties can be forged in specific circumstances, as with the existence of a dedicated public-private agency that focuses on promoting differentiation and value added for exports.

The development of integrated traceability systems calls for a strong public-private coordination, organized around an agenda with clear priorities. It is necessary to build mechanisms that enable an overall internationalization vision for every value chain in order to avoid the usual conflicts among chain participants that threaten system development. At the same time, these efforts should include all the public sector areas that can contribute to their advancement – and not only the areas closest to the agribusiness sector. Natural candidates to play the leading role of system coordinators are the sanitary authorities or other regulatory agencies, such as SENASA and INAC in the SITC and SNIG cases, respectively.

Notes

1. The COVID-19 crisis also prompted a swift adoption of new protocol requirements – for example, for meat exports to China.
2. For a more detailed description on how traceability systems work, see Hallak and Tacsir (2021).
3. According to FAO (2017), a batch is a set of units of a single product that can be identified by its consistent composition, origin, etc. and is part of a shipment. The way in which a batch becomes operational varies from one product to another, based on technological limitations, transport and storage mechanisms, as well as regulations. For a traceability system to prove effective, the batches starting an industrial process must remain intact or be separated, but they should never be grouped or mixed.
4. Gupta and Kaul (2017) review the different technologies available for traceability solutions across the food value chain.
5. IBM's FoodTrust stands out among the existing solutions available for individual systems. This traceability system enables subscribed producers to make relevant information available to supermarket chains like Walmart or Carrefour. Thus, supermarkets can recall products in a matter of seconds. Tools like this one, which build direct ties between producers and retailers, are expected to become increasingly important for retailing in developed markets over the coming years.
6. By design, the information included in integrated systems is directly inputted without the need of intermediation by an individual system.
7. In a similar spirit, Canavari *et al.* (2010) distinguish between baseline traceability and traceability plus.
8. Some certifications already provide some of the information sets that would prove desirable for advanced traceability systems. Thus, it may be important to include this information as a first step in upgrading basic systems into advanced systems.
9. Unfortunately, there are no specific studies in the literature that quantify the relative costs of individual vs integrated traceability systems. These costs may depend on several factors including the technological infrastructure already in place and the complexity of the sanitary and phytosanitary requirements. Due to their specificity, the identification and the analysis of the relative costs of alternative types of traceability systems deserves more focused research.
10. Despite the ability of integrated systems to cross-check information, physical audits in the field and in packing or processing plants are usually necessary as well to ensure that the information entered by firms is valid. This type of audits is also necessary when individual traceability systems are in place, although they are presumably more costly and less effective as the information used across individual systems is not standardized.
11. It would probably not be necessary for public players like sanitary or regulatory authorities to build traceability systems for sectors exporting commodities in bulk, which feature large players with global operations, such as cereals or soybean trading companies. These firms can develop their own traceability systems, as they can coordinate the necessary information flow with all their suppliers in order to guarantee a recall. They also know their clients' needs well, which enables them to build advanced traceability systems.
12. This challenge has grown larger with information digitalization and government IT integration, as producers may fear that their data be submitted to other State areas for taxing purposes.
13. The *Alimentos Argentinos* seal created by Argentina's Ministry of Agriculture, Livestock and Fisheries provides an example of an information set that might be used for an advanced traceability system but has failed to be valued as a differentiating attribute in foreign markets, as it has not been promoted strongly enough in those markets.
14. For more detailed descriptions of INAC's traceability system, see Bianchi *et al.* (2016), Paolino *et al.* (2014), Rius (2015), Zurbriggen and Sierra (2015) and González *et al.* (2021).

15. The share of exporting producers is a relevant variable in the development of a funding scheme for traceability systems. In Uruguay, virtually all producers and beef-packing plants export their products.
16. This attribute has not been intensely used, as the additional slaughtering cost are rarely offset by the premium prices consumers are willing to pay for this detailed information.
17. The EU's Quota 481 requires that cattle must be less than 30 months old and be held in pens for at least one hundred days with high-energy content feeding. For the Hilton quota, instead, the cattle must be fed exclusively grass since weaning and should not have been raised in confinement or holding pens for feeding purposes.
18. For more information on INAC, see González *et al.* (2021).

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