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WORKING-PAPER – UMR MOISA

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Pesticide safety risk, food chain organization, and the adoption of sustainable farming practices. The case of Moroccan early tomatoes

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Résumé

La sécurité sanitaire pour les fruits et légumes frais est depuis une vingtaine d'années une préoccupation majeure pour les consommateurs et les gouvernements, notamment ceux du Nord de l'Europe. Notre étude s'intéresse au contrôle de la sécurité sanitaire pour les filières de légumes frais. Elle précise notamment comment s'organisent ces filières pour se conformer aux standards privés de la grande distribution et ainsi pouvoir accéder aux marchés d'exportation et aux marchés nationaux dits modernes. La plupart des travaux traitant de l'adoption de référentiels certifiés de bonnes pratiques agricoles ou de techniques de protection intégrée ne prennent pas en compte l'organisation de la filière et les interactions entre les acteurs de cette filière. Pour pallier ce manque, l'article analyse l'influence des relations verticales en se basant sur la Théorie des Coûts de Transaction. Plus précisément, on considère les incitations et les procédures de gestion mises en œuvre par les stations de conditionnement pour contrôler les producteurs et gérer le risque lié aux pesticides. Deux enquêtes ont été réalisées dans la région du Souss-Massa-Drâa au Maroc. La première considère trente stations spécialisées en tomate. Elle fournit des résultats contrastés quant à l'hypothèse selon laquelle, plus la filière est intégrée et plus le contrôle est réalisé à travers une supervision directe, et moins à travers la mise en œuvre d'un système incitatif. La seconde enquête considère 86 producteurs. Elle confirme que les filières les plus intégrées sont les plus efficaces en termes de protection des investissements spécifiques dans la production raisonnée. L'adoption de la lutte biologique et des référentiels de bonnes pratiques agricoles est ainsi plus importante lorsque les serres sont détenues par des stations privées, plutôt que par des producteurs indépendants des stations.

Abstract

Fresh produce pesticide safety risk has grown into a major concern of North European consumers and governments for the last twenty years. Our study expands on safety control issues and gives insights into how fresh vegetable chains organize to comply with retail private safety standards and thus get access to export and modern domestic markets. Most studies on the adoption of good agricultural practice certifications and integrated pest management overlook the influence of food chain organization. Building on Transaction Cost Economics, our paper aims to fill this gap by studying the influence of vertical linkages, more precisely the incentives and managerial procedures crafted by packing stations in order to control farmers' behavior and manage the pesticide safety risk. Two surveys have been conducted to that purpose in the Moroccan Souss-Massa-Drâa region. Our first survey of thirty tomato packers provides only mixed results about our first hypothesis: that the more the supply chain is integrated (from contracted growers to full ownership) the more the control of pesticide safety risk is achieved through direct supervision rather than outcome-based incentives. Our second survey of 86 producers confirms that integrated chains are more efficient in safeguarding specific investments in safety management, which results in greater diffusion of biocontrol and good agricultural practice certification within the greenhouses that are owned by private packers rather than independent farmers.

Keywords

Food safety, Pesticides, Integrated pest management (IPM), Good agricultural practices (GAP), Transaction costs, Vertical organization, Fresh vegetables

JEL: D23, Q13, Q16

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INTRODUCTION

Fresh produce pesticide safety risk has grown during the last twenty years into a major concern of North European consumers and governments. Product standards and more recently process standards (Good agricultural practices and integrated pest management) have turned into the most efficient solution to control and reduce the level of pesticides on fresh produce. Defined by a variety of public and private actors, safety standards are implemented and controlled at different levels of the chain including retailers and importers. Accordingly, safety control has turned into a key issue for the development of Mediterranean fresh produce export and local markets (Martinez and Poole, 2004).

Our study expands on safety control issues and gives insights into how fresh vegetables chains organize to comply with private safety standards and thus get access to export and modern domestic markets. There is a huge body of literature on the adoption of safe farming practices and certifications in agriculture, however most farm-scale studies overlook the influence of food chain organization in the adoption process and few empirical studies investigate inter-organizational factors.

Building on Transaction Cost Economics (Barzel, 2005; Williamson, 1985, 1991), our paper aims to fill this gap by studying the influence of vertical linkages, more precisely the mechanisms and governance structures crafted by packing stations in order to control growers' behavior and manage pesticides safety risk. Our hypothesis is that food chain governance structures have different capabilities to induce compliance with safety requirements and encourage the adoption of safe farming practices.

The paper is based on a qualitative study of the Moroccan fresh vegetable chain, followed by surveys of tomato growers and packing stations in the Souss-Massa-Drâa province, the main region for fresh vegetable production in Morocco.

The paper will be organized as follows. Section 1 analyses the governance problems drawing on Transaction Cost Economics. Special attention is paid to performance evaluation, asset specificity and coordination issues. Section 2 presents the survey methodology and section 3 the management of food safety in the Moroccan fresh vegetables chain. To better understand how tomato buyers are managing their suppliers to enforce compliance, we then analyze in section 4 the relationship between the organizational structures of the supply chain (integrated production, cooperative, contract farming) and their governance mechanisms. In section 5, we study the influence of chain organization on the adoption of integration pest management and good agricultural practices by farmers.

1. GOVERNANCE IN FOOD SAFETY

1.1. The rise of private regulation

While tariff barriers are progressively eliminated, non tariff barriers have been raised in particular in the safety and phytosanitary domain. Fresh produce export chains are mainly concerned with pesticide safety issues when targeting European markets. Although European consumers are more and more demanding as regards to pesticide produce safety, there is no true safety-based differentiation at the consumer level, which would justify a premium to be paid by the consumer (Combris et al., 2012). Absent such a market based driving force, public and private control of public and/or pesticide safety standards becomes the main spur of grower safety effort.

Private control is exercised at different levels of the chain and by different operators (Fulponi, 2006), mainly over residues (Maximum residue limits or MRL standards), good agricultural practices (Global GAP or individual retailers GAP such as Tesco, Ahold, Carrefour, etc.) and traceability (2005 EU Food Law).

In the customer country, control is most frequently passed by public agencies at the boarder level and by private retailers and/or importers by direct sampling at the platform level or by having exporters send residue analysis and/or GAP certificates. In some countries, public/private co-regulation is implemented for residue control (Henson and Caswell, 1999). In the exporting country, most of the control is done by the exporter company on the product and sometimes on the production process. Public authorities may sometimes intervene when a public good is at stake, which is the case for customer countries with phytosanitary requirements (not the case of EU) (Codron et al, 2002).
It is worth mentioning that the motivation for private control in the customer country may be exacerbated or mitigated by State criminal liability regimes and above all by the activism intensity of NGO consumer associations. Such institutional differences may have significant consequences on chain organization and the nature of standards imposed on growers. For instance, customers in countries with strong consumer NGO like Germany are more prone to focus on residue control while customers in countries with criminal liability relying on the retailer are more prone to require a GAP certificate and also to bypass the importer/broker (Codron et al, 2006).

1.2. Explaining the adoption of sustainable farming practices

The fresh vegetable sector is one of the most advanced worldwide in terms of control of the production process, with the development of integrated pest management - especially in greenhouse production - and an increasing focus on GAP certifications.
For example, the diffusion of low pesticide input practices in French protected vegetable production has been assessed in a recent study (Brismontier et al., 2009). According to the authors, conventional pest control does not exist practically any more in French greenhouses, because nearly all of the producers are monitoring pests and reasoning their pesticide applications. Integrated pest management (thereafter IPM) implies the simultaneous control of multiple pests, their monitoring, the use of thresholds or economic injury levels to apply pesticides, and the integration of suppressive tactics, including the use of natural enemies or antagonists (Elher, 2006). Since the early 90s, research on the adoption of IPM and good agriculture practices has flourished in the field of agricultural economics. For the purpose of this research, we have reviewed 27 studies dealing with IPM or GAP adoption published between 1991 and 2011, representing 44 cases (Codron et al., 2012b)[1].
A first critical point for research is to define IPM, as they are many operational definitions according to crop, region, pest classes and government-sponsored programs (Fernandez-Cornejo et al., 1998; Kogan, 1998)[2]. Most of farm-centered adoption models deal with the use of a single technique, generally scouting for invertebrate pests (Caswell et al., 2001; Fernandez-Cornejo, 1996; Fernandez-Cornejo and Jans, 1996; Fernandez-Cornejo and Kackmeister, 1996; Mcnamara et al., 1991; Yee and Ferguson, 1996). Other work try to explain the use of biological control (Caswell et al., 2001; Fernandez-Cornejo and Ferraiolli, 1999), crop rotations (Caswell et al., 2001) or cultural and pesticide-efficiency techniques (Fernandez-Cornejo and Ferraiolli, 1999).
To avoid the shortcomings of binary response, researchers have measured the intensity of adoption, which may be assessed by the number or IPM techniques (Lohr and Park, 2002; Maumbe and Swinton, 2000; Sharma et al., 2011), the magnitude of their use (McDonald and Glynn, 1994) or the total workforce dedicated to IPM (Beckmann et al., 2006). Numerical, count or categorical data are therefore used to model adoption. Other studies modeled the diffusion of IPM with duration models, the dependant variable being the lag of adoption in years (Fuglie and Kascak, 2001).

[1]Recent literature surveys on close topics include Knowler and Bradshaw (2007) on conservation agriculture, Prokopy et al. (2008) and Baumgart-Getz et al. (2012) on agricultural best management practices.
[2]For example, the EC define IPM as "the rational application of a combination of biological, biotechnical, chemical, cultural or plant-breeding measures, whereby the use of plant protection products is limited to the strict minimum necessary to maintain the pest population at levels below those causing economically unacceptable damage or loss" (Directive 91/414/EEC).

Studies on the adoption of GAP certificates avoid those measurement problems, as certificates are precisely defined by public or private regulations (GlobalGAP, Fair Trade, integrated fruit production, etc.) so that the identification of "adopters" is undemanding (Asfaw et al., 2010; Burton et al., 1999; Cazals et al., 2009; Dorr and Grote, 2009; Kersting and Wollni, 2011; Souza Monteiro and Caswell, 2009; Mzoughi, 2011).

The main findings of this farm-scale centered literature are summarized in Table 1. For integrated pest management, the positive effect of education, short trainings and access to extension services confirm that IPM is a complex, human capital and information-intensive technology (Carpentier, 2010; Fernandez-Cornejo, 1998). Farmer's age has a negative effect, which suggests that older producers have fewer incentives to invest and may be more reluctant to accept newer techniques (even though their larger experience could favor a better control over complex techniques). Empirical results confirm that off-farm activities compete for on-farm managerial time and may present a constraint to IPM adoption (Dorfman, 1996; Fernandez-Cornejo, 1998). Farm size, by far the most widely investigated factor of IPM adoption, generally increases the probability of adoption or the speed of diffusion. There are different explanations for this important result. Given the fixed transaction and information costs associated with innovations, there may be a critical threshold on farm size (Just et al.; 1980, Fernandez-Cornejo, 1998). Also, larger farms have more resources to manage complex processes (Carpentier, 2010) and size could be correlated to other factors, such as wealth or access to credit (Feder et al., 1985). Revenues are also sufficient to offset the financial risk of experimentation with multiple practices (Lohr and Park, 2002). Other variables associated with IPM are crop irrigation and biophysical environmental factors such as land quality, good soils (Caswell et al., 2001; Yee and Ferguson, 1996) and generous rainfalls, where greater pest and diseases pressure may be expected (Fuglie and Kascak, 2001). Other factors studies show mixed results (for example, crop diversification). Work on the adoption of GAP certificates (last column in Table 1) show quite similar results than IPM literature, although farm size has often a negative effect on certificate adoption (a counter-intuitive result that is not explained by authors).

Table 1. Determinants of the adoption of sustainable farming practices: summary.

Factor		**IPM adoption**	**GAP certification**
Farmer	Age	-	0
	Education	+	+
	Short trainings	+	+
	Off-farm activity	-	-
	Access to technical assistance/consultants	+	+
Farm/Capital	Farm size	+	-
	Importance of family labor	+	NA
	Land ownership	0	NA
	Irrigation	+	+
	Crop diversification	0	NA
Environment	Soil quality/Land productivity	+	+
	Rainfalls/Pests and diseases pressure	+	NA
Marketing	Marketing contracts	0	0
	Producer organization membership	NA	+

Source: Authors (See Codron et al., 2012b).
+: in most studies, increases the probability of adoption/the speed of diffusion.
-: in most studies, decreases the probability of adoption/the speed of diffusion.
0: mixed results.
NA: variable not included in studies surveyed.

Regarding organizational factors, it is worth mentioning that the adoption literature concentrates almost exclusively on within-farm organization factors such as partial or full involvement of the head farmer in the farm activities, division of work between family and wage labor. With the noticeable exception of the relationship with consultants, food chain linkages are seldom encompassed. Only two studies test the effect of contracting on farmer behavior: marketing contracts have a negative effect on the adoption of pesticide-efficiency techniques in the peach sector (Fernandez-Cornejo and Ferraiolli, 1999), whereas forward contracting positively influence scouting for peanuts (Mcnamara et al., 1991). No study focuses on food chain governance. Work on certificates adoption provides some results on cooperatives: the number of years within a farmer group (Asfaw et al., 2010) and the belonging to large producer organization (Souza Monteiro and Caswell, 2009) positively influence GlobalGAP adoption. In contrast, credit access through farmers' groups has a negative effect on adoption in a Thai fruit and vegetables study (Kersting and Wollni, 2011). However, the authors do not provide any explanation of their results.

1.3. The role of food chain organization

Governance problems

In food supply chains, firms are faced with all sorts of organizational (or governance) problems. While some of them can be resolved through contracts based on pure outcome-incentives such as price premium, other ones need the implementation of non-standard vertical organization (Ménard, 2012). Contracts introduce predictability and allow people to allocate resources with greater confidence. They also allow market participants to share risk, and are used to motivate performance (Milgrom and Roberts, 1992). Following the typology of Bijman (2007), we concentrate on three governance problems in pesticide safety risk management: performance evaluation (or measurement), coordinating interdependent activities, and safeguarding specific investments. All three are sources of transaction costs and potential inefficiencies.

Performance evaluation. Moral hazard may be used to qualify a principal-agent issue, where the principal has imperfect information regarding the actions that the other party takes during the implementation of the contract. The issue is related to problems of behavioral uncertainty, evaluating individual performance (Alchian and Demsetz, 1972) and measuring product or asset characteristics (Barzel, 1982, 2005). In the case of fresh vegetables, the effort to reduce the level of pesticide residues is unobservable to the buyer. The grower has therefore an incentive to cheat and under-supply safety, because he will benefit from the buyer company safety-based reputation on the end market without bearing the costs of safe farming practices. Note that the free-riding problem is similar within vegetable cooperatives, where the cooperative safety reputation on the end-market is a common property resource of the grower members. In the greenhouse tomato industry, the farmer costs to comply with safety requirements at the farm level include extra labor (scouting for insects and diseases, elimination of contaminated plants, etc.), additional inputs (low toxicity pesticides, resistant crop varieties, pheromone traps, etc.) and material investments (for example insect nets and curtains). It also includes opportunity costs such as the respect of pre-harvest interval. Moreover, those good practices and IPM techniques are supported by costly consulting services and grower trainings so that an opportunistic grower will try to save on these costs (Figure 1).

Safeguarding. The second main contractual hazard is the risk of hold-up over the quasi-rent created by a specific asset investment (Alchian and Woodward, 1987; Williamson, 1985). Asset specificity, which features as a key source of contractual hazards in Transaction Cost Economics (TCE), encompasses investments (land, material, technical, immaterial, and human assets) that increase the productivity or quality of a process, but have little or no value elsewhere. They are sunk costs and increase the bilateral dependency between trade partners. In marketing channels, asset specificity relates particularly to knowledge of original methods of sale (Rindfleisch and Heide, 1997). In the broiler industry, commitment to factory farming requires substantial physical investments at farm level; in the event of the purchaser backing out, switching costs may be high if there are few alternative partners within a reasonable

commuting distance (Knoeber, 1989). In the wine industry, yield limitation imposed by the buyer with the aim of increasing quality may be considered as a dedicated asset (Codron et al., 2012a). Producers of perishable fruits and vegetables are particularly vulnerable to buyer's opportunistic behavior (Masten, 2000). As asset specificity creates dependence, the contractual relationship becomes costly if there is a risk of a contracting party deciding to breach the initial contract, or threatening to do so in order to renegotiate more favorable terms. In the fresh vegetables sector, the most advanced exporters in terms of safety management have heavily invested in traceability systems and food packaging certification (BRC, IFS, ISO, etc.). They also actively brand their products as safe and environmentally-friendly. On the producer side, the fine-tuning of pesticides risk management includes demanding alternative techniques such as biocontrol and organic farming, and managerial investment to comply with farm certificates (Global GAP, Tesco).

Coordination of interdependent activities. According to Williamson (1991), adaptation is the central economic problem. The interaction between bounded rationality and environmental uncertainty increases the costs of adapting formal contractual agreements. These transaction costs include the costs of gathering and processing information, organizing decision-making, and an opportunity cost of lost synergy (Bijman, 2007). Coordination costs make incomplete contracting appealing for buyers and sellers. In this case, some residual decision rights are allocated to one or the other trade partner, to make joint adaptation. The rights over non contractible actions may be called residual rights (or economic rights), as opposed to the specific or legal rights that may be included as a formal clause in a contract (Demsetz, 1998). In food safety management, an example is compliance with MRL, which is simultaneously dependent upon farm decisions (date of pesticide application) and supply chain constraints (harvest packing and shipping).

Properties of governance structures

Governance mechanisms are embedded in governance structures, which are classically defined in Transaction Cost Economics as market, hybrid and hierarchy (Williamson, 1991). Those canonical governance structures have different properties (Williamson, 1991). Markets are providing outcome-based incentives, with competition between third-party suppliers and buyers and performance rewards used to provide incentive-alignment (for example in agricultural marketing contracts). If the legal system helps to resolve commercial disputes, markets however lack strong safeguards to prevent rent appropriation. Conversely, in hierarchies, resources are integrated into a single command. Firms use direct supervision, monitoring and internal dispute settlement procedures to align incentives. The incentive intensity is lower within hierarchies, because workers' compensation is not only linked to individual performance, but also to the willingness to cooperate and accommodate work changes (Bijman, 2007). Firms use standard operating procedures, but also encourage permanent mutual adjustments, which are especially useful when it necessary to jointly adapt interdependent activities in face of high environmental uncertainty (Milgrom and Roberts, 1992; Williamson, 1991).

Figure 1. Properties of governance structures.

		Governance mechanisms		
Nature of Governance problem	**Governance mechanisms**	**Market**	**Hybrid**	**Hierarchy**
Performance evaluation	Outcome-based incentives	++	+	0
	Administrative controls	0	+	++
Coordination of interdependent activities	Decision rights	0	+	++
Safeguarding	Ownership	0	0/+	++
	Semi-strong safeguards	0	+	0

Ménard (2012) emphasizes the role of authority in exercising control over and instilling “discipline” in the members of hybrid organizations. Authority is only exerted on a limited subset of rights, and because it is based on mutual consent, it is different from the relationship within a firm, where the worker is subordinated to hierarchical ties. In subcontracting, one firm has extended decision rights to adapt the contract (Ménard, 2012). In this case, the transfer of decision rights could be an efficient way to reduces transaction costs, but it leads to the possibility of opportunistic behavior on the part of the principal (Barzel, 2005; Arrunada et al., 2005). As a result, the agent accepts to transfer rights only if he is granted monetary advantages or can benefit from efficient private enforcement mechanisms, such as social norms, relational trust, or reputation.

Governance mechanisms in safety risk management

Outcome-based incentives. Contracts with pricing schemes such as quality-contingent payment (bonuses or penalties) are used to channel an agent's efforts in a particular way. They are routinely incorporated into marketing contracts in food chains (Hueth et al., 1999; Jang and Olson, 2010). In the livestock industry, contracts with carcass merit program based on grading are replacing traditional auction markets and over-the-counter agreements (Hueth and Lawrence, 2006; Mazé and Ménard, 2010). Jang and Sykuta (2009) show that marketing contracts could be used not only to provide incentives for quality in hog procurement, but also to increase inter-temporal consistency, with price and non-price provisions designed to enforce the packer's quality requirements over the duration of the contract.

The combination of outcome-based rewards and product quality measurement provide strong incentives to growers. In the case of pesticides safety management, vegetable buyers are using penalties (downgrading of harvest) rather than quality-contingent payment. The threat of contract termination for non-compliance is another strong incentive. Compliance is assessed with residues analysis and the implementation of residue control plans.

Administrative controls. When food output measurement is difficult, a solution may be to monitor and control farm input, provided that such action is not itself too costly. More generally, administrative controls are an alternative mechanism to outcome-based incentives (Williamson, 1991). They are of course widely used within vertically integrated organizations, with internal quality procedures. They are also a feature of production contracts. Input control is becoming popular in the grain and oilseeds chains to overcome contractual hazards associated with difficult-to-measure quality (Lambert and Wilson, 2003, Sykuta and Parcell, 2002). Quasi-vertical integration is widespread in the broiler industry worldwide (Knoeber, 1989; Ménard, 1996) and it is an increasing feature in vegetable productions (Olesen, 2003). In pesticides risk management, the control of farm inputs includes the prohibition of certain molecules, and, conversely, the requirement to use specific active ingredients, and eventually commercial products, the use of auxiliaries’ species. Monitoring encompasses field visits of station’s technicians, the checks of crop/spraying information sheets, their centralization at the station and other internal traceability tools.

Decision rights. When there is little uncertainty on task programmability and a strong correlation between agents' effort and output, a food buyer could theoretically design a complete production contract, including production practice rules (Jang and Sykuta, 2009). However, environmental uncertainty is a salient feature of agricultural production (Allen and Lueck, 2003; Masten, 2000), which often makes it impossible to draw up such complete contracts in the real world.

This is especially true as regards to pesticides safety management, where decisions about chemical spraying have to be made according to the evolution of diseases and pest pressure, crop growth, climate (kinetic of molecules), and pre-harvest interval. Even for controlled environments such as greenhouses, it is impossible to write technical specifications covering all possible events. As a result, to make joint adaptation, it may be more efficient to transfer decision rights to the party with the greatest expertise. Hu and Hendrikse (2009) show that in the Chinese fruit and vegetables, under contract farming, many decision rights are shifted from farmers to firms, including the use of fertilizers and pesticides.

In the case of pesticides risk management, these decision rights include the rate (active ingredients per hectare) and the date of application. The molecules themselves could be adjusted during the growing season, according to technical (pest pressure) or commercial needs (change in a customer's requirements).

Figure 2. Governance of safety risk management.

Nature of Governance problem	**Source of transaction costs**	**Governance mechanisms**
Performance evaluation	**Behavioral uncertainty** Effort to reduce the level of pesticides residues in fresh fruit and vegetables	**Outcome-based incentives** – Performance reward: Quality-contingent payment (bonuses or penalties), downgrading of harvest (first choice to off-grade), downgrading for the whole campaign, contract termination; – Output measurement: Multi and mono-molecule residue analysis, residue control plan.
		Administrative controls – Input control: Prohibition/requirement to use active ingredients, commercial products, auxiliary species; – Task monitoring: Field visits, checks of crop/spraying sheets, traceability.
Coordination of interdependent activities	**Environmental uncertainty** Joint adaptation of greenhouses and packing stations	**Allocation of decision rights** – Interdependent decisions to manage pesticide risk (respect of MRL), e.g. date of chemical application, harvest and vegetable shipping.
Safeguarding problem	**Asset specificity** Specific investments in food safety management (IPM, GAP, supplier and buyer certifications)	**Safeguards** – Ownership: vertical integration into vegetables production; – Semi-strong safeguards: long term contract, reputation, producer organizations with control over decision making.

Ownership. The integration within a single property is the most powerful tool to secure highly specific investments and dedicated assets (Klein et al., 1978; Williamson, 1985). Since the seminal work of Monteverde and Teece (1982), numerous empirical studies show that asset specificity is associated with forward or backward vertical integration (Klein, 2005; Macher and Richman, 2008; Rindfleisch and Heide, 1997). Firms simultaneously choose the level of specificity and the organization that will provide safeguards against the risk of rent appropriation (Williamson, 1985). Reciprocally, vertically-integrated firms are well fitted to protect new appropriable investments. For vegetables buyers, vertical integration into greenhouse production is therefore a strong mechanism to protect specific investments, on the vegetables growing side (IPM and GAP) as on the packing side (brand-name capital and certifications).

Semi-strong safeguards. Other kinds of safeguard will accommodate medium levels of asset specificity. Non-legal enforcement mechanisms include reputation, relational contracting and private arbitration. All can help to overcome critical organizational problems in business transactions. Klein (1996) gives insights into the "self-enforcing range" of contracts, where the private enforcement capital of firms (i.e. their capacity to impose sanctions by threatening to terminate the relation or to damage the other firm's reputation) defines the extent to which parties honor their commitments (for an application in the agri-

food sector, see Mazé and Ménard, 2010). In relational contracting, interpersonal trust, norms of obligation and cooperation, open communication and the sharing of information are supporting transactions (Eccles, 1981; Poppo and Zenger, 2002). Community enforcement works well in small groups, where low information costs and cultural homogeneity encourage retaliation and black-listing, with a risk of losing future business (Richman 2004). In food chains, producer organizations with control over decision making are other efficient ways of mitigating moral hazard and externalities (Bijman, 2007; Raynaud et al., 2009). Cooperative could also build internal procedures to control free-riding and promote collective action.

1.4. Empirical predictions

In agri-food chains, processors and distributors are using different governance mechanisms to procure agricultural commodities. These mechanisms are more or less suited to mitigate opportunistic behavior and induce compliance with product and process food safety requirements. Building on Transaction Cost Economics, we put forward two propositions on the influence of vertical linkages on safe farming practices and certificates in fresh vegetables. They are empirically tested on the Moroccan tomato chain.

1. With regard to the performance evaluation problem, we assume that the more the supply chain is integrated (from contracted growers to full ownership of greenhouses), the more the control of pesticides safety risk will be solved through direct supervision of the production process, rather than outcome-based incentives through residues analysis and penalties (e.g. downgrading of tomato harvest or farm). We conducted a survey of tomato packing stations to test this prediction (See section 4 for the main results).
2. Turning to asset specificity and the rent appropriation problem, our hypothesis is that integrated chains are more efficient in safeguarding specific investments, so that advanced integrated pest management techniques and good agricultural practices will be more diffused within greenhouses owned by private packers, rather than by independent or cooperative producers. A survey of tomato growers has been conduced to test the prediction (See section 5 for results).

2. METHODOLOGY

As safety risk management can be implemented both at the greenhouse and at the packing station level, the analysis must consider the two sides of the chain. Thus, for the purpose of the study, two surveys have been performed in the Souss-Massa-Drâa province, a region situated at the West South of Morocco, and which produce around 60% of Moroccan tomato (80% of greenhouse production).

If Moroccan official directories identify fruit and vegetable packing plants, they do not identify vegetables producers. Hence, the sampling methodology is different depending on the population considered. The survey of producers has been conducted from November 2010 to December 2011 and refers to the 2009-2010 season. This survey is based on snowball sampling, which consists on a progressive identification of the population. As a first step, producers have been identified from interviews with key informants and surveyed. These producers had then named others farms, which have been surveyed, and so on. This progressive construction allowed surveying 86 tomato growers in the Souss-Massa-Drâa region. Administering the questionnaire required first an exploratory stage, where the key players of the fruit and vegetables sector have been interviewed. These key players are: GAP and organic farming certifying firms, farm input distributors, professional associations, public agencies and governmental departments. After this exploratory stage, the questionnaire was tested to validate both its relevance and that questions do not lead to confusing answers. The questionnaire has been performed on face-to-face.

The sampling methodology for the station questionnaire was not defined according to snowball sampling. The APEFEL (Moroccan association of fruits and vegetables exporters-producers) inventories 84 fruit and vegetable packing plants in the Souss-Massa-Drâa region for the season 2010-2011. First, we surveyed the stations whose tomato suppliers were already interviewed. Because all stations were not willing to answer,

others firms have been randomly selected in the APEFEL list to reach a total of thirty stations. The survey has also been conducted on face-to-face.
Surveyed packing stations represent 35.7% of the total of packing stations within the Souss region. Three types may be considered according to the degree and nature of vertical integration:

- Vertically-integrated packing stations, producing all tomato supply on their own farms (therefore "integrated firm").
- Other privately-owned packing stations, sourcing from different tomato producers (therefore "contractor"). Vegetables may be sourced both from external growers and owned farms.
- Growers' marketing cooperatives with own packing station.

The two latter have multiple suppliers. Thereby, despite a fairly good match between the packing stations and the producers surveyed[3], a matched analysis cannot be performed for statistical reason: indeed, such a match would lead in over-representing coops and contractors, in the detriment of integrated firms.

3. SAFETY RISK MANAGEMENT IN MOROCCO

Morocco fresh produce exports are 90% oriented towards Europe where the main concern of consumers is chemical contamination by pesticides used in the production process. This concern has drastically increased over the last two decades. Absent pesticide-based market differentiation, control has become the key safety management device of public and private entities. While a diversity of private standards has developed in particular regarding the production process (GAP standards) and the product (MRL, forbidden molecules), a number of significant regulation changes have occurred at the national and EU levels (Codron et al, 2006). Changes at the EU level are mainly i) the list of authorized molecules which has been extensively revised and drastically reduced; ii) national Maximum Residue Limits for pesticides (MRLs) which have been harmonized by EU authorities (Regulation (EC) No 396/2005); iii) greater responsibility which has been imposed on food operators at all stages of the chain by the EU Food Law Regulation 178/2002 which came into force in 2007; iv) traceability which has been imposed from grower field to retailer by the same EU Food Law regulation with applicability from the 1st of January 2005.
In this section, we will first briefly present the main features of the Moroccan export and distribution chain to Europe, and then highlight how and why public and private operators both in Europe and Morocco implement and articulate safety control.
Morocco has a long history of fresh tomato export-oriented production, mainly driven by the French EU quota and tariff-based regulation. Exports have varied between 100 kt and 150 kt during a long period (from the 1960s to the 1980s). From the early 90s Moroccan exports have started to climb reaching an average of 150 kt until the mid 90s, 200 kt in the 2000s and 250 kt in the mid 2000s. In recent years, this growth has accelerated and exports are now above 400kt (421 kt in 2009). The recent rapid increase is essentially due to the progress of classic loose tomato, which increases from 200,000 tons to 330,000 tons, between 2004-2005 and 2008-2009. The effort of diversification of the exporters can be observed by the significant breakthrough of the cherry tomato, the exports of which grew from 11,000 tons in 2004-2005 to almost 50,000 tons in 2009-2010. The cocktail tomato presents a similar trend, while the cluster tomato shows certain stagnation in the export.
France is by far the main market with still around 75% of total volume exported. Diversification is significantly developing towards Spain, UK, Switzerland and Russia. Exports to Italia, Netherlands, Slovakia and Germany still account each one for less than 1% of total volume.
Morocco has signed several agreements with the European Commission. The last negotiation was completed in 2012 and reinforces Morocco preferential access to European markets for several agricultural products. The greatest preference is for tomatoes. The current Moroccan quota is currently 210,000 tons. Within the next four years, the quota is planned to be increased by 52,000 tons. The

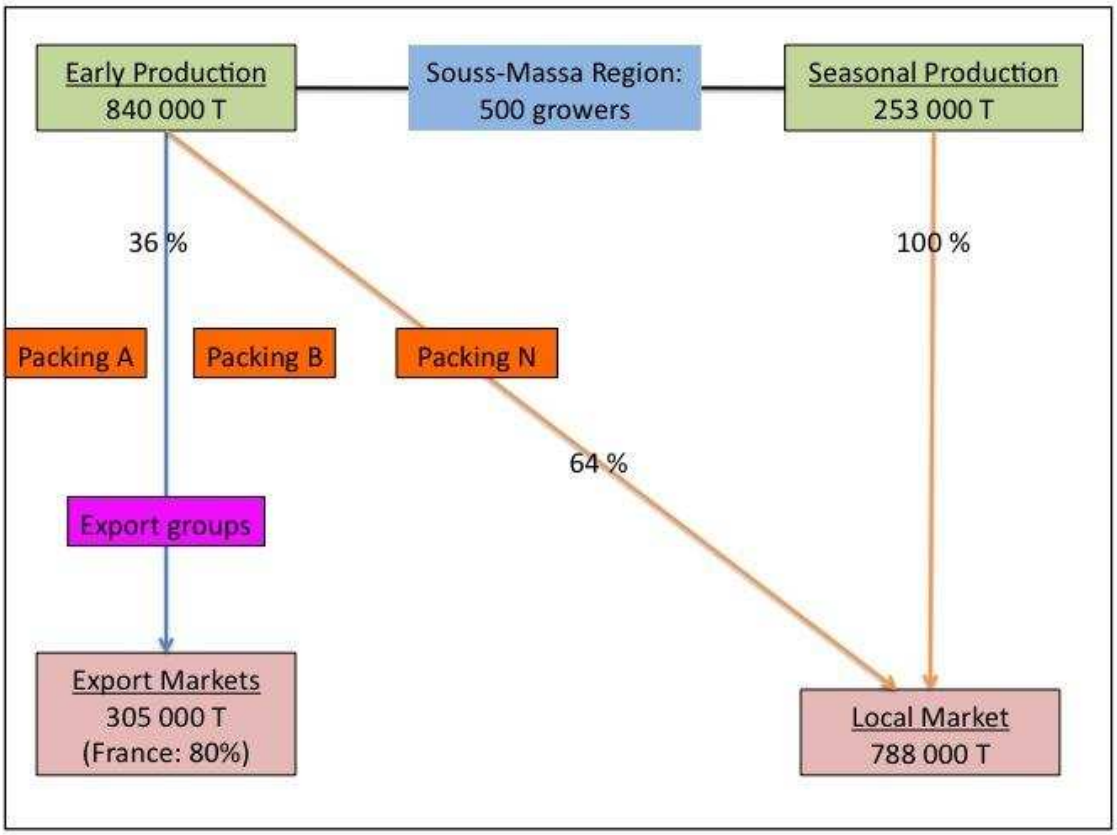
[3] On the 86 growers surveyed, 53 could be unambiguously linked to one of 21 packing stations.

minimum entry price for Morocco is considerably lower than for other countries. Resulting from a good negotiation that Morocco concluded with the EU in 2003, a general framework of tariff contingency is applied to tomatoes imported from Morocco for the period from October to April with a preferential entry price of 46.1 Euros/kg and an ad valorem duty of 0 %. Above this contingency, the regime for Most Favored Nation is applied.

Three levels may be considered in the vertical tomato export chain (Figure 3):

- the growing level with about 500 tomato growers;
- the packing level with about 80 packing stations providing beyond the technical services related to packing, technical assistance and information to growers about pesticides, certification and markets;
- the export level with about 15 exporting groups the role of which is i) to negotiate export quotas with the government, ii) to ensure the provision of export services, particularly logistics and transportation and iii) sometimes to aggregate consignments together under a single marketing strategy.

Figure 3. The markets of fresh tomato in 2009.



Source: Conseil Général du Développement Agricole (2011).

A few of these exporting companies have international strategies and establish in France to better control the product flow and sell directly to supermarkets, while a majority of exporters market their products by dealing with importers: 90 % of the Moroccan tomato exports transit through French importers.

A survey carried out by Ubifrance in 2005, shows that Moroccan exporters have a diversity of legal status (limited liability companies, co-operatives, etc.) and property rights (cross shareholdings, strategic alliances between groups, etc.). Three main types of organization may be identified, discriminating by the level of forward and backward integration (either ownership or contracting):

- Export groups like Maraissa (Azura), Rosaflore (Idyl), Doche (Matysha) or Delassus which are fully vertically integrated, from production to import activities. Such groups are characterized by a mixed structure of both European and Moroccan capital. They dispose of platforms in Spain or in France and may perform a full control of their export activities.
- Export groups like Domaines Royaux, Soema (Avryl) or Armona which are only integrated backward into production, either through ownership or contracting. With no forward integration into import activities, they sell their products through French importers.
- Export groups like OCE and Salam which are not integrated, neither forward or backward.

In the customer country, safety control is performed both by public and private entities. EU public agencies require traceability and self control by chain operators. They directly control for compliance with MRL standards at the boarder or at further stages in the distribution chain. On the private side, importers and supermarket chains are the main players in safety control. Control by importers and retailers are achieved through residue analysis over the product and/or control or certification over GAP standards (Global GAP, Nature Choice, Ahold, Filière Qualité Carrefour…) (Fulponi, 2006). Pesticide residue analyses are performed to verify that products comply with the public MRL standard. Residue control is also performed to comply with the private MRL standards of some European retailers who require more stringent standards than public ones.

A high proportion of North European countries supermarket chains have adopted Global GAP while South European countries retailers are only a minority to be Global GAP members and to require Global GAP from growers. While GAP standards usually include as a major requirement, a number of residue analysis to be performed by growers (one analysis per grower per year and per certified crop for Global GAP), most supermarkets usually perform their own analysis by direct sampling at the platform level.

Depending on the country configuration of Law and market forces, there is more emphasis on GAP certification (or control) or on residue private standards and their control (Codron et al, 2006). Forces of utmost importance in driving the modalities of control are the criminal liability regime and consumer association activism. They differ across countries. While the UK regime is governed by the due diligence principle and puts full liability on the retailer (Hobbs and Kerr, 1992; Henson and Caswell, 1999), the responsibility in the French liability regime rests on the first agent to introduce the product in the French supply chain (Art. L 221-1; Art. L 212 -1, French Consumption Law). However, in case of retailer branding, the retailer is considered as the first agent to introduce and therefore bears full liability. Consumer NGO activism also widely differs across European countries, reaching its highest levels in countries like Austria, Germany or Netherlands.

Configurations with emphasis on GAP certificates are more specific of countries like UK with liability regimes fully relying on retailers. Within such a liability regime, retailers need to supervise the whole import supply chain and look for governance solutions that minimize their safety risk (Holleran et al, 1999; Henson and Hooker, 2001). A first option is to delegate safety control to large-scale export firms. A second option is to impose private standards on all their suppliers (GlobalGAP). This last option tends to be prevailing as long as suppliers from developing country are not yet all large-sized firms.

Configurations with emphasis on residue analysis are more specific of countries with a high degree of consumer NGO activism (countries like Germany). Of course, both types of control may co-exist within a private safety management strategy/policy. In countries like France or Spain, where GlobalGAP is not required by retailers and where activism is weak, safety risk management greatly varies across retailers (Codron et al, 2002). Retailers differ by the modalities and the number of residue analysis. They may also implement individual proprietary GAP standards. More pressure of control is of course exercised on growers as soon as private branding is at stake.

At the importer level, control greatly depends on the level of vertical integration. As soon as there is tight coordination within a stable relationship between the importer and the exporter or between the importer, the exporter and the grower, control over the production process is easier and allows for reduction of control over the product. At the importer collective level, public/private co-regulation is sometimes implemented for residue control. It is the case in France where importers who bear full responsibility according to the criminal liability regime and are imposed self-monitoring since 1998 at the national level,

collectively organize under public agencies supervision to perform the boarder safety control. They have signed a collective agreement in which they commit to achieve a given number of residue analysis. The collective arrangement is voluntary and allows for better efficiency and reduction of residue analysis cost control (Codron et al, 2007).

Private and public actors of the Morocco fresh produce export chain have been long aware that safety is a key challenge for competitiveness on export markets, in particular EU markets. Exporters individually and collectively organize to comply with EU regulation (traceability, MRL and forbidden molecules) and private customers standards (at the grower level, GAP certificates and extra MRL).

While the response to private GAP and residue standards is mostly individual (see further the findings of our survey), efforts to comply with residue constraints are also collective, given the potential negative externalities that arise when an exporter is controlled at the EU boarder with an excess of residues (Codron et al, 2003). As a result, the whole export chain has organized into efficient[4] collective structures of safety control, in particular EACCE and LOARC (Codron et al, 2012b).

EACCE controls residues on exported fruits and vegetable at the packing level and, in some litigious cases, at the field level. Controls are systematic. In 2009/2010, 1,498 samples of vegetables were taken. The group of pesticides to be analyzed in a sample is decided by EACCE inspectors, depending on the last pesticides recorded by the producer. Produce are usually exported before the analytical result is known. When non-compliance is identified, EACCE writes to the exporter concerned and stops any future export of produce coming from the same plot of the farm. EACCE requests an explanation from the exporter, including data on traceability and records of pesticide applications. EACCE does not consider informing the EU importer. EACCE owns six analysis laboratories, located in the main regions of production of Morocco. Two laboratories, in Casablanca and Agadir, are accredited according to ISO 17025 by the French Accreditation Body COFRAC. EACCE plans to achieve accreditation of the remaining laboratories in 2012. Accreditation provides control flexibility for Moroccan products at their entry in the European market, especially at the French border city of Perpignan.

4. PACKING STATIONS

Vegetable packing stations have different legal status and vertical organization. Among the stations that we surveyed, 8 are cooperatives, the other 22 have a private status. In this last group, we distinguish between integrated firms (8) and contractors (14) that are supplied by multiple independent growers. A gradient of integration can thus be defined from the less integrated form (contractor) to the most (integrated firm). The cooperative is an intermediate organizational form, where different growers have their packing outlet in common property. The underlying assumption of our study is that the more the station is vertically integrated, the more safety risk management is based on administrative controls rather than on outcome-based incentives.

For all stations surveyed, more than 95% of the tomato production is exported (Table 2). We observe that integrated firms have the most important level of production with on average 14,000 tons, while for the others the figure is around 10,500 tons. For pesticide residue control, integrated stations realize 68 multi-residue analysis and 120 mono-residue analysis. These stations have a low control pressure for multi-residue analysis, with 23 analyses for every 10.000 tons. Conversely, cooperatives have a higher control pressure for multi-residues with around 100 analyses per ton[5]. The result on pesticide analysis suggests that hierarchies are indeed performing less output measurement than hybrid organizations.

[4]Only 13 cases of rejection of Moroccan fresh produce (no one of them concerns tomatoes) reported by the EU RASSF (Rapid Alert System for Food and Feed http://ec.europa.eu/food/food/rapidalert/index_en.htm) database for the last three years (01/01/2008 until 28/10/2011) while the non compliance rate was 2% (DG-SANCO 2011-6027).

[5]Note that the average number of analysis by farm supplying the cooperative is less than 10, lower than for integrated firms (68). However the comparison is misleading, since the latter often own many farms, with a larger total greenhouse area. An example is AZURA, a vertically-integrated exporter that owns 25 tomato farms in the region.

However, contrary to our hypothesis, no relation exists between food chain organization and the intensity of sanctions. Two indicators of the intensity of sanctions in case of safety non-compliance have been defined: on one hand, the intensity of sanction for the supplier in case of punctual non-compliance (on a tomato lot); on the other hand the intensity of sanction in case of recurrent anomalies during the growing season. In the two cases, we observe that sanctions are not statistically different whatever the organization. Going to the agricultural practices, we observe that the more the station is integrated and the more it drives production. For pesticide management, we created a scale that measure the intensity of requirements from the station to the grower: the scale goes from 1 if there is no requirement at all to 3 if there are requirements in terms of active ingredient, pesticides brands, and also application periods. While the average indicator is 2.43 for integrated firms, it is only 1.88 for cooperatives stations; however the difference is statistically non significant.

Table 2. Product safety management.

	Mean (StdDev)			**Student's t-test [1]**		
	Contractor (a)	**Cooperative (b)**	**Integrated firm (c)**	**(b) vs (a)**	**(c) vs (a)**	**(c) vs (b)**
N	14	8	8			
Multi-residues analysis per 10,000 tons of tomatoes	35.17 (27.71)	99.90 (103.56)	22.99 (14.48)	**		*
Multi-residues analysis per supplier	5.19 (6.97)	9.10 (7.45)	59.00 (63.43)		***	**
Intensity of sanction in case of non-compliance (scale: 1-3)	2.79 (0.89)	2.50 (0.76)	2.57 (0.79)			
Intensity of sanction if recurrent anomalies (scale: 1-3)	2.00 (0.78)	1.50 (0.53)	1.86 (0.90)			
Intensity of pesticides requirements (scale: 1-3)	1.93 (0.73)	1.88 (0.83)	2.43 (0.79)			
Tomato production (tons per station)	10,188 (7,993)	10,813 (8,960)	13,625 (10,719)			
Grade-outs (%)	20 (9)	26 (11)	23 (7)			
Exports (% of first choice production)	82.66 (35.06)	94.95 (5.01)	96.42 (2.17)			

[1] Blank: non-significant; * p< 0.10; ** p<0.05; *** p<0.01.

Conversely, while forward-integrated organizations provide more command to their farm managers, they perform less pesticide residue control plan than cooperatives, for which this control is systematic (Table 3). Stations can also require from their growers to be certified. We observe differences between organizations, albeit not statistically significant according to Pearson's Chi-square test. While integrated firms required more frequently than others Tesco Nature's Choice (Nurture) and GlobalGAP certification, cooperatives and contractors insist more on organic farming certificate. Beyond requirements on chemical protection and GAP certification, stations are also involved in the direction of tomato growers' practices via the monitoring of greenhouse crop sheets, and the provision of advices on pest and diseases control: regular crop newsletters or field visits by the station's quality manager. We can observe that the monitoring of producers via crop sheets is more frequent for cooperatives than for other packing stations. Once implemented, the sheets are almost systematically centralized at the headquarters for traceability reason. Considering the technical advice to producers, we can note that cooperatives and integrated firms develop the same actions. Both send a quality manager to visit farms and both send a regular newsletter. Contractors realize more field visits to farms (93%, against 75% for others). In the same way, there are more likely to send a regular newsletter (65% against 25% for others stations).

To summarize the results, regardless of vertical organization, Moroccan packing stations are strongly involved in the management of their suppliers' farm practices. Stations manage differently depending to their extent of chain integration, albeit these differences are not statistically significant (See test in last column, Table 3).

As greenhouses, packing plants can be certified. IFS (International Features Standard) Food and BRC (British Retail Consortium) 'Global Standard for Food Safety' are the two most important food safety certificates worldwide. Considering IFS, we observe that the more the station is integrated, the more likely it has implemented this certificate (28.6% against less than 15% for other groups). As regards to marketing strategies, almost all stations develop their own proprietary brand. The only difference observed is in the frequency of private brands developed for customers (distributors, supermarkets, exporting groups, etc.), which are more likely implemented by integrated firms than by the others.

Table 3. Management of agricultural practices.

	N				Frequency				Pearson's Chi2 test
	Contractor	**Cooperative**	**Integrated firm**	**All**	**Contractor**	**Cooperative**	**Integrated firm**	**All**	
Own brand	14	8	6	28	100.00%	100.00%	85.70%	96.60%	n.s.
Other brands (e.g. retailer)	4	4	4	12	28.60%	50.00%	57.10%	41.40%	n.s.
Any GAP certificate	14	8	7	29	100.00%	100.00%	100.00%	100.00%	n.s.
Organic farming	0	2	1	3	0.00%	25.00%	14.30%	10.30%	n.s.
TNC	2	3	3	8	14.30%	37.50%	42.90%	27.60%	n.s.
GlobalGAP	13	7	7	27	92.90%	87.50%	100.00%	93.10%	n.s.
Frequent field visits	13	6	5	24	92.90%	75.00%	71.40%	82.80%	n.s.
Regular newsletter	9	2	2	13	64.30%	25.00%	28.60%	44.80%	n.s.
Crop sheet	9	7	5	21	64.30%	87.50%	71.40%	72.40%	n.s.
Centralization of crop sheets	12	8	7	27	85.70%	100.00%	100.00%	93.10%	n.s.
Residue control plan	12	8	6	26	85.70%	100.00%	85.70%	89.70%	n.s.
IFS	2	1	2	5	14.30%	12.50%	28.60%	17.20%	n.s.
BRC	12	6	6	24	85.70%	75.00%	85.70%	82.80%	n.s.
All (column)	14	8	7	29	100%	100.00%	100.00%	100.00%	n.s.

BRC: British Retail Consortium; IFS: International Features Standard; TNC: Tesco Nature's Choice.
n.s.: non-significant.

5. TOMATO PRODUCERS

The key questions of the research are to determine to what extent greenhouse producers manage pesticides safety risk and how the differences could be explained. We have considered two advanced safe practices, first the fact that producers use or not biocontrol of insects with auxiliaries, and second the fact that they are or not GlobalGAP certified. The first practice is considered as such, with the adopter and non-adopter categories, while for the second one, three groups have been defined:

- Early adopters, those who were certified before 2007.
- Followers, certified between 2007 and 2010.
- Non adopters.

In 2010, 80% of producers of the sample of producers were GlobalGAP certified and fell into the first two groups, half in each one. To validate the relevance of the arbitrary break-up between early adopters and followers, two others thresholds have been tested: 2006 and 2008. The stability of the empirical results confirms the initial choice. In the same way, considering the two criteria of safety management proved to be important because both bring specific information. Indeed, if 50% of producers using auxiliaries could be classified as GlobalGAP early adopter and 40% as followers, followers are a heterogeneous population in terms of biocontrol. This heterogeneity justifies taking into account these two in our analysis.

As regards to explanatory variables, the management of the safety risk can be apprehended through five indicators: (i) the individual characteristics of farmers, (ii) the structural characteristics of their farms, (ii) (iii) their perception about the production risks linked to pests and diseases, (iv) the intervention of a third-party in the safety risk management, and (v) the chain organization, which is the motivation of the research. In the following paragraphs, the indicators will be analyzed successively.

Considering the structural characteristics of farm estates, we note that, on average, producers have an utilizable agricultural area (UAA) of around 70 ha, of which 50 ha are dedicated to greenhouse production (See Table 4 and Table 5 in appendix for statistical tests). Producers with an advanced safety management scheme are largest than the others. While the agricultural area for producers with auxiliaries is about 90 ha, the average for non-users is beyond 25 ha. The same gap is observed if we consider the greenhouse area: 70 ha against only 20 ha. This last difference is explained by the overall structure, because the proportion of farm land dedicated to greenhouse production is 75% on average for all producers, regardless if they use or not auxiliaries, and there is no significant difference between of the percentage of land dedicated to greenhouse. In short, producers using biocontrol are larger, but no more specialized on greenhouse production than other producers.

We also observe a difference in terms of size considering the gradient of GlobalGAP adoption. Early adopters differ sharply from others: their agricultural area is 2.25 times higher than the area of followers, and four times higher than the area of the non-certified farms. The result is observed considering greenhouse area. However - and conversely to producers using auxiliaries - primary adopters are slightly more specialized on greenhouse production than others, with a rate of 65% against 50%. The size effect is logically also observed through the labor employed on farms. The structural characteristics (size in terms of land and labor) are not correlated with higher crop productivity. Indeed, on average, loose classic tomato yield is about 185 tons per ha for all producer categories.

Considering individual characteristics of farmers who develop such management schemes, we note that they are older and more educated. They have more often a second, non-agricultural activity: 72% of biocontrol adopters declare an external activity, against 50% for non-users. In the same way, 75% of Global GAP early adopters have another source of income, while they are less than 50% for the others. These results on pesticide safety risk management are consistent with the adoption/diffusion literature, which concludes that structural and individual characteristics of farms are key factors of sustainable practices in agriculture.

The main objective of greenhouse safety risk management is to meet fresh vegetable chain requirements. The benefits of adoption will therefore be higher for the grower, if the change in farm practices is associated with traceability and quality control. Two indicators may be considered: the realization of an external farm audit by a third-party (different from the requirements of GlobalGAP and other safety certificates) and the implementation of an internal residue control plan. Data show that almost of producers have implemented a residue control plan. However, the figure is different for the external audit: tomato growers with advanced safety risk management are more likely to pay for such an audit than others. Hence, around a third of producers using auxiliaries are audited, while no non-user. In the same way, GlobalGAP certified growers (20% with external audit) differ from non-certified producers (7%).

Table 4. Characteristics of sustainable farming adopters.

	Auxiliaries (No)	Auxiliaries (Yes)	GG Early adopters	GG Followers	Non - adopters	All
	25	61	35	36	15	86
1. Farmer characteristics						
Age of farmer	46.32	53.47	54.06	50.46	47.27	51.35
Education	3.44	3.88	3.94	3.69	3.43	3.75
Other sources of income (%)	52	72	74	64	53	66
Coop membership (%)	64	57	63	53	67	59
2. Farm characteristics						
Total farm area (ha)	23.43	88.84	108.31	48.83	30.40	69.82
Greenhouse area (ha)	18.26	68.58	94.89	27.24	22.55	53.95
Total labor	16.64	50.41	61.86	24.92	28.60	40.59
Area under full property (%)	51.54	55.65	53.41	56.46	52.10	54.46
Tomato (% of UAA)	52.89	58.74	65.61	54.48	43.20	57.04
Greenhouse (% of UAA)	77.41	73.71	82.81	69.62	68.42	74.78
Loose classic tomato (% of tomato area)	52	45	46	50	43	47
Loose classic tomato yield (tons per ha)	194.42	184.34	184.72	185.88	196.57	187.27
3. Risk assessment						
Disease pressure (scale: 1-10)	1.40	1.88	2.01	1.54	1.58	1.74
Pest pressure (scale: 1-10)	2.29	2.79	3.00	2.41	2.37	2.64
4. Third-party						
External quality audit (%)	0	28	23	22	7	20
Residue control plan (%)	96	98	100	100	87	98
5. Food chain organization						
Integrated firm (%)	16.00	49.98	51.43	27.78	6.67	33.72

The literature on integrated pest management shows that biotic and abiotic factors also influence farmer decision making. Our hypothesis was that the differences in phytosanitary pressure may explain the rate of IPM adoption within vegetable growers. Two synthetic indicators are used, one for pests and one for diseases, calculated from a self-assessment of different species. Pests considered in the questionnaire are the main pests in Moroccan tomato greenhouses: mites, whiteflies, moths, Tuta absoluta and nematodes; diseases considered are Alternaria, anthracnose, bacteriose, botrytis, cladosporiose, fusariose, downy mildew, powdery mildew and black narrox. For each species, the producer provided a risk assessment from 1 to 10 on a ten-point scale. Synthetic risk indicators for pests and diseases are computed from the non-weighted average of all listed species. These two indicators are considered separately, because of their mediocre correlation (57%). Overall, the risks remain low, below 2 on average for diseases and 3 for pests. We observe that producers with advanced safety management perceive higher risks, both in terms of tomato pests and diseases. One explanation is that IPM and good agricultural practices are not only implemented to manage food safety risk and get market access, but they are also more efficient techniques than chemical protection to tackle high phytosanitary pressure. However, at least for insects, there is a reverse causal explanation: these alternative techniques (particularly biocontrol) need fine-tuning and do not suppress the risk but maintain low population of insects, whereas the objective of chemical protection is to eradicate pests.

Last but not the least, to answer our second research question, we studied the influence of food chain organization on the adoption of IPM and safety certificates. Tomato growers are differentiated depending on their degree of integration within the chain, in a typology consistent with TCE and the former classification of packing stations:

- Vertically-integrated producers, from greenhouse production to packing ("integrated firm"). The farm owner is the sole owner of the station, or the co-owner with non farming associates.
- Contractors, which are delivering tomato to private stations in which they have no stakes.
- Cooperators, which are members of a cooperative and deliver to a cooperative station.

A few producers have declared no affiliation to any packing station; in such a case, no information is indicated concerning their organizational pattern.

The results of statistical analysis are that integrated firms are more likely to be advanced growers in terms of safety management. We observe an over-representation of producers using auxiliaries (50% versus 16%) and GAP early adopters (51% versus 27% for the followers and 7% for the others). The differences are statistically significant (Last raw in Table 5).

CONCLUSION

The literature is basically silent on the influence of marketing and supplier-buyer linkages on the adoption of integrated pest management and good practice certificates in agriculture. Also, to date, little empirical work has been done on the governance mechanisms used by vegetable buyers to manage pesticide safety risk jointly with growers, and more specifically their choice between product or process control, with eventually the allocation of decision rights. The governance mechanisms of vegetable packers are indeed more or less suited to mitigate opportunistic behavior and induce compliance with food safety requirements.

Our paper tackles those two issues. Based on surveys made in the Moroccan fresh tomato export chain, it provides empirical evidence that the organization of the food chain is an important and often overlooked feature of safety control.

The survey of fresh vegetable packers in the Souss-Massa-Drâa province provides mixed results about our first hypothesis: that the more the supply chain is integrated (from contracted growers to full ownership), the more the control of pesticide safety risk is be solved through direct supervision, rather than outcome-based incentives.

The survey of early tomato producers which are large size growers with cropping and marketing behavior very similar to those of developed countries provides more salient and original results. While it confirms the role of traditional factors influencing sustainable farming practice adoption (e.g. farm structures, grower education), it shows that vertical organization plays a significant role on adoption. In particular, it shows that integrated chains are more efficient in safeguarding specific investments, which enables to put forward that advanced integrated pest management techniques and good agricultural practices are more diffused within greenhouses owned by private packers, rather than within greenhouses of independent and cooperative growers.

A main limit of the study is the rather small number of firms surveyed. The size of the packing house sample is certainly an explanation of our rather inconclusive results regarding the choice between strong incentives and direct supervision. For statistical reason, a match between grower and station data was not performed. Such a combined analysis would answer the question of whether the wider diffusion of biocontrol and certificates is also influenced by the governance mechanisms tailored by vegetable buyers.

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APPENDIX

Table 5. Characteristics of sustainable farming adopters.

T-test and chi-square test [1]	**Auxiliaries**	**GlobalGAP**		
		Reference: Early adopters		**Others vs followers**
		Followers	**Others**	
Age of farmer	***		**	
Education	***	*	**	
Other sources of income (%)	*			
Coop membership (%)				
Total farm area (ha)	***	***	***	
Greenhouse area (ha)	***		***	
Total labor	**			
Area under full property (%)		*		
Tomato (% of UAA)		**	**	
Greenhouse (% of UAA)			**	
Loose classic tomato (% of tomato area)				
Loose classic tomato yield (tons per ha)				
External quality audit (%)	***			
Residue control plan (%)			**	*
Disease pressure (scale: 1-10)	***	**		
Pest pressure (scale: 1-10)	***	**		
Integrated firm (%)	**	**	***	*

[1] Blank: non-significant; * $p < 0.10$; ** $p<0.05$; *** $p<0.01$.