Estimating the Impact of Small-Scale Farmers' Collective Action on Food Safety:

The Case of Vegetables in Vietnam

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Summary. – This paper is an original empirical tentative to explain collective action outcome in the domain of food safety. We examine conditions and institutions that influence pesticide residues level in vegetables using econometric analysis on data gathered by 60 farmers organizations in Vietnam. Findings suggest that collective action affects safety by providing members with technical assistance, monitoring and certification. The expected increase of free-riding in larger groups is not an issue when members are properly supported and monitored. The contribution of public authorities and ecological conditions to safety remains controversial while market forces do not seem able to drive the production of safer vegetables.

Key words – collective action, food safety, pesticide residues, vegetables, Asia, Vietnam

Q13 - Agricultural Markets and Marketing; Cooperatives; Agribusiness

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1 Introduction

The Green Revolution has contributed to increase crop productivity and enhance food security in many developing countries by promoting high-yielding variety adoption combined with intensive use of potentially hazardous agricultural chemical (Hazell & Ramasamy, 1991). Furthermore, the worldwide dramatic urbanization and the raise of income in urban areas led to an increasing importance of peri-urban agriculture and to a steady growth of vegetable production in order to meet the expanding urban demand for more diverse food (FAO, 1999). Vegetables attract a wide range of pests and diseases and may require high applications of pesticides to control them. Due to several reasons, farmers in developing countries often apply pesticide in excess, misuse them or use illegal acutely toxic insecticides (Tixier & De Bon, 2006). There is evidence of high pesticide use in peri-urban areas of some countries with health exposure of urban consumers as a consequence (Dinham, 2003).

Today's consumers in both developed and developing countries have become increasingly concerned about food safety. There is an ongoing debate about the most effective and desirable mechanism for achieving an appropriate level of food safety in the food supply chain. A consistent body of literature exists on the role played by public authorities and private actors in ensuring food safety (Caswell & Johnson, 1991; Henson & Caswell, 1999). On the public side, direct *ex ante* regulation based on product, process and firm standards is applied to the whole chain from input suppliers to produce retailers. Companies that do not comply with standards may be sanctioned. Product civil and criminal liability is *ex post* regulation. Only criminal liability applies in the case of pesticide residues since damages that could result from absorbing pesticides residues most often occur in the long term and have complex causes, thus making the burden of proof to injured parties excessively heavy. [1] Direct regulation and criminal liability represent incentives for companies to engage in effective safety control. Alongside public intervention, private mechanisms of food safety such as self regulation or third party certification, have also developed substantially and now play an important role in the supply of safer food.

In developed countries, public and private safety regulations get progressively intertwined and manage to ensure food safety (Henson & Caswell, 1999; Martinez *et al.*, 2007). This is not the case in most developing countries where government institutions are significantly weaker and voluntary quality assurance schemes are still emerging. While there are some examples of exporting firms in developing countries that successfully adapt to international standards in order to access more remunerative markets (Henson, Masakure, & Boselie, 2005; Roy & Thorat, 2008), considerable worry remains about food safety in their less demanding domestic market (Chemnitz, Grethe, & Kleinwechter, 2007). Furthermore, it is frequently asserted that small producers have more difficulties coping with the increasing prevalence of safety standards on international as well as national markets (Narrod *et al.*, 2009; Reardon *et al.*, 1999; World Bank, 2005). The reasons often mentioned are: (i) compliance with standards often incurs high fixed costs which, combined with smallholders' poor access to credit, favors larger producers due to economies of scale; (ii) other participants of the chain may prefer to cooperate with larger farms in order to reduce the transaction costs related to the communication and downstream monitoring activity and; (iii) smallholders usually have a short history of getting involved in safety management and lack the necessary reputation. As a result, small producers may be excluded from high value markets and their economic situation may deteriorate.

A solution advocated for small farmers to overcome these constraints is collective action (Reardon *et al.*, 2009). Collective action in the domain of agriculture and food, is recognized by several scholars as providing several benefits: better access to input, better access to market, reduction of transaction costs, increase of bargaining power and provision of collective reputation, serving as a guarantee in the marketing of the product (Bosc *et al.*, 2002; Markelova *et al.*, 2009; Winfree & McCluskey, 2005).

Collective action in the domain of food safety is still an emerging topic in academic literature. A main focus so far has been to show how collective action may facilitate the access of small farmers to demanding markets in terms of safety. Major actions that have been identified for fresh produce are i) increasing farmers' capacity to undertake joint investments (e.g., infrastructures, labeling and certification); ii) providing farmers with information, technical assistance and proper inputs; iii) making possible vertical integration or contract farming; and/or iv) building favorable conditions for the establishment of public-private partnership (Berdegué *et al.*, 2005; Henson, Masakure, & Boselie, 2005; Moustier *et al.*, 2010; Narrod *et al.*, 2009; Roy & Thorat, 2008).

Yet, the existing papers on collective action for food safety are mostly of a qualitative nature and do not provide econometric tests on the benefits of collective action to reach food safety. Besides, they do not concentrate on the major challenge of collective action, i.e., free-riding. Free-riding can be defined as the opportunistic behavior that leads self-interested individuals to enjoy the benefit accruing from a collective effort, while contributing little or nothing to the effort (Olson 1965). In the fresh produce industry, the collective good at stake is collective reputation which largely conditions market opportunities. The stake is all the higher and the control of free riding all the more difficult that traceability, Integrated Pest Management (IPM) certification and/or residues analysis are absent or costly to implement, which is the case in Vietnamese vegetables growers organizations.

Several scholars have contributed to identify a number of conditions and institutions that might limit free-riding and facilitate the creation and maintenance of the collective good. The purpose of our research is to provide first empirical evidence and econometric tests on the effectiveness of some of these conditions and institutional arrangements in limiting the misuse of pesticides in farmers organizations (FOs). Our paper is original for two reasons. First, we don't know of any other research using econometric tools dealing with collective action in the domain of food safety. Furthermore, although institutional theories recognize that the analysis of emergence and outcomes of collective action should consider other scales of analysis besides a single community (Ostrom, 2005), it is rare to find a study like our paper that includes in the analysis contextual factors, namely public interventions, market forces and ecological conditions, that can either create incentives for the provision of safety or enable producers to supply safer vegetables. [2] The case study has been carried out in the peri-urban area of Hanoi, Northern Vietnam, where the pesticide residues are a cause of great concern for urban consumers and where public and market institutions have not yet been able to guarantee adequate level of food safety.

The rest of article proceeds as follows. In the next section, we introduce the literature on enabling conditions for effective collective action and safety provision. In Section 3 we present the FOs and the issue of pesticide residues in Vietnam. In Section 4 we specify the conceptual framework, the research questions and the various hypotheses to be tested. In Section 5 we illustrate the data collection method, the measurement of variables and the regression model. Finally, in Section 6 we present and discuss our findings, and in Section 7 we draw the main conclusions and some policy recommendations.

2 Theoretical insights

Field studies and evidence from all around the world have shown that the “tragedy of the commons” is not unavoidable and people can efficiently cooperate and build institutions to govern collective goods (Ostrom, 1990). Most of the literature on collective action is related to the management of common-pool resources, such as fisheries, forests, rangeland and water resources. Agrawal (2001) synthesized the works of several previous authors (including Baland and Platteau, 1996; Ostrom, 1990; Wade, 1988) in an effort to identify factors that can lead to successful collective action outcomes, but little agreement exists on the direction, size, and significance of their effects.

Some of these enabling factors are related to the characteristics of the group which influence the outcome of collective action. One of the most controversial issues relates to the size of the group. Olson (1965) argues that smaller groups are more likely to engage in successful collective action because, as the size of the group increases, members realize that their individual contribution to the collective good becomes more and more marginal and therefore, are more prone to free-ride on the other members of the group. For instance, Winfree and McCluskey (2005) show that in large groups the incentive to provide quality decreases. But other scholars have remarked that the relationship between group size and collective action is not very straightforward and a tradeoff between increase in free-riding and potential economies of scale exists. For example, Marwell and Oliver (1993) find that the size of a group is positively related to the outcome of collective action since collective action tends to happen when a critical mass of interested and resourceful individuals can coordinate their efforts.

According to most of literature on the commons, the level of social capital within the group is another characteristic that can positively affect the outcome of collective action. Social capital refers to the complex of traditional social ties, trust, and norms of reciprocity that can lead to increased levels of cooperation among the group members (Baland & Platteau, 1996; Wade, 1988). However, it is difficult to find relevant indicators to measure social capital. The duration of the relationship is one of them. It is justified by the fact that long-lasting groups are more likely to be engaged in successful collective action because members have already established patterns of shared understanding, reciprocity and reputation (Araral, 2009; Meinzen-Dick *et al.*, 1997). Other authors use the level of kinship within the group as social capital proxy (Di Falco & Bulte, 2010).

Education is also considered important for successful collective action. It has a twofold valence as limiting the free riding (Lyne, Gadzikwa, & Hendriks, 2008) and increasing individuals' capacity to absorb more content and put it into practice (Caswell *et al.*, 2001; Fernandez Cornejo, 1998).

A further group characteristic that, according to the literature, can affect the likelihood of successful collective action is the extent to which group members depend upon the collective good. Demsetz (1967), and Dietz, Ostrom and Stern (2003) argue that the salience of the good to the livelihoods of group members is one of the most important condition which facilitates collective action. If the good is salient enough to the members, they would be more likely to be interested in protecting it and investing time and energy to create new institutions.

Organizational factors are another set of factors influencing collective action. A large amount of literature on new institutional economics has argued for the importance of institutional arrangements that the group may establish in order to improve the outcome of collective action.

For instance, Baland and Platteau (1996) and Ostrom (1990) agree that the ability of members to collectively establish and modify clear rules and obligations adapted to local conditions can significantly reduce free-riding and enhance the quality of collective action. The provision of a forum of discussion also develops this ability by giving individuals the opportunity to discuss their problems with one another, find common solutions and supply themselves with shared rules (Varughese, 1999).

Once rules have been established, they should be monitored and enforced to ensure compliance and limit free-riding. Ostrom (1990) argues that, without a reliable internal monitoring system, there can be no credible commitment to follow the rules. Group members can play a major role in directly monitoring each other's activity or they can choose to delegate this task to entrusted and qualified members or to inspectors they hire. Moreover, in order to limit the opportunistic behavior, a system of graduated sanctions should be applied to members that are found to violate the rules (Ostrom, 1990; Wade, 1988).

According to Agrawal (2001), most scholars on collective action have paid only limited attention to factors external to the group, such as states, markets and ecological conditions and have ignored that local groups and institutions which are the focus of their analysis are often created in conjunction with the external and nonlocal environment. [3] This has prevented the emergence of a better understanding of how external factors interact with local institutional arrangements and influence the output of collective action. Literature focusing on external factors like public authorities or market forces that may influence firm behavior as regards to food safety, may fill this gap of understanding.

First, public authorities can support producers in increasing food safety level by providing the required technical advices and resources. Several empirical studies have shown that farmers receiving specific training and technical assistance on IPM practices have been able to significantly reduce their dependence on pesticides (Caswell *et al.*, 2001; Rejesus *et al.*, 2009).

Furthermore, as already mentioned, public authorities, besides setting statutory food safety standards, are directly involved in monitoring their compliance and imposing sanctions in case of violations. A number of studies show that sound public enforcement of safety regulations represents an incentive for producers to undertake measures designed to ensure food safety (Henson & Caswell, 1999; Segerson, 1999; Starbird, 2000). Nowadays, most countries operate pesticide monitoring schemes, but the magnitude, reliability and scope of such schemes vary considerably from country to country (Shaw, 1999).

A discussion has arisen in recent years dealing with the potential for private self-regulation of food safety in contrast to public "command and control". A small but important literature has tried to determine the conditions under which market forces create adequate incentives for firms to invest in food quality and safety. Segerson (1999) shows that for credence goods a strong mandatory threat (e.g., the threat of a more costly system being imposed) is a necessary and sufficient condition for firms to adopt safety measures voluntarily. According to Venturini (2003) the firm must be able to promote or value the voluntary nature of its initiative with the consumer and the government intervention, in the form of independent certification, may serve to increase the credibility of voluntary approaches vis-à-vis the consumers. [4] Other researches argue that the incentives necessary for the adoption of voluntary approaches to food safety may come from the modern retail system. In particular, supermarkets are seen as actors who are able to impose food safety in food network. They develop private standards as substitutes for non-existent or inadequate public standards in order to compete with the informal sector by claiming superior product attributes (Reardon & Timmer, 2005). The private incentives for food safety created by supermarkets are primarily incentives in terms of market access, sales volumes and potential premium. Codron, Giraud-Héraud and Soler (2005) show that the commercial risk represented by the supermarkets constitutes a strong, private incentive against which the firms try to protect themselves by developing voluntary measures in order to increase the safety level, and hence to preserve the commercial relationship.

Finally, the safety level of the final products may depend on the locally-specific ecological and biophysical characteristics. Several researches show how the cultivation in contaminated areas or irrigation with contaminated water, also contribute to increasing the residual levels in crops above the allowed limit (Tixier & De Bon, 2006; Toan *et al.,* 2009).

3 Institutional framework, pesticide residues and food safety initiatives in Vietnam and Hanoi province

Up to the late 1980s, Vietnam used to follow the Soviet model of central-planning and agricultural production was organized into agricultural production cooperatives and state farms (Wolz, 2009). In 1986, the market mechanism was introduced with the adoption of a renovation policy called "*doi moi*" and farmers were given back the right to control the land and to decide how to produce, although the land remained under State ownership. With the adoption of the Cooperative Law in 1997 (revised in 2003) the old cooperatives should be transformed into membership-oriented service cooperatives and new agricultural service cooperatives could be established from scratch (Wolz, 2009). Nowadays in Vietnam the bulk of agricultural production still takes place in FOs that may present a diversity of forms. The transformed cooperatives have maintained a rather large membership base (between 200 and 2,000 members) and the main focus is still on paddy production. Often, producers of these cooperatives who share a specific interest in one production activity, such as fish or vegetable production, have associated in smaller organizations (between 10 and 250 members), while still being officially members of the transformed cooperative. Finally, new cooperatives are characterized by a small number of members (between 10 and 60), focus on the promotion of only one production activity and are considerably more commercially-oriented than the other types of FOs. Each FO is administered and supervised by a management board whose size is generally proportional to the size of the membership base: one to three persons working on part-time basis in smaller groups, and three to seven persons either working on part-time basis or employed as specialized full-time staff in larger groups.

The *doi moi* and the Cooperative Law resulted in an impressive growth of agricultural production. Furthermore, in the last two decades, the spectacular economic development and the rapid urbanization have led to an increase in the demand for more diverse and better quality products especially in urban areas (Figuié *et al.*, 2004). Between 1995 and 2005 vegetable production area and volume increased by 60% and 81%, respectively (FAOSTAT, 2010). Vegetable production became not only a critical component of subsistence systems in more remote and impoverished communities but also a key industry in specialized peri-urban areas (IFPRI, 2002). Currently, the bulk of vegetables supplying Hanoi is produced in peri-urban districts (Moustier *et al.*, 2006). Due to the very limited farm size, vegetable growers began to increasingly rely on large quantities of chemical inputs in an attempt to boost their productivity. Between 1991 and 2007 pesticides use in Vietnam increased from 15,000 to 76,000 tons (Hoi, Mol, & Oosterveer, 2009). Low-cost pesticides (organophosphates, carbamates and pyrethroids) with high toxicity (WHO classes I and II) are very commonly used and application rates are much higher than recommended rates (Dinham, 2003). The overuse of pesticides, the use of banned pesticides and the lack of compliance to the prescribed pre-harvest intervals are the main causes for high pesticide residues in the marketed vegetables (Tixier & De Bon, 2006).

Nowadays, pesticides take up a major place among the food safety concerns in Vietnam. Figuié and Moustier (2009) argue that the main food safety concerns, except during period of crisis such as the avian influenza crisis, relate to pesticide residues in fruits and vegetables and antibiotic residues in meat. More than 80% of consumers interviewed in Hanoi mentioned concerns about food risk associated with pesticide use on vegetables (Figuié, 2003). In 2002, more than 7,000 cases of food poisoning from pesticide residues were reported in Vietnam, involving over 7,500 people and causing 277 deaths (Hoi *et al.*, 2009).

In response to rising public concern about food safety, the Vietnamese government began to seek to ensure higher safety of foodstuffs. While, according to the law, food business operators are legally responsible for the safety and hygiene of the food they produce and trade, the government is directly involved in the enforcement of safety standards (SRV, 2003). With specific regard to pesticides the main responsibility is given to the National Plant Protection Department (PPD), division of the Ministry of Agriculture and Rural Development (MARD). Among the others, PPD is in charge of inspecting farmers' fields and implementing pesticide residue control on sampled products. However, concern remains about inconsistent and inadequate surveillance and enforcement and high corruption level among inspectors (World Bank, 2006). Furthermore, in case of violation, applied sanctions, if any, are not clearly defined and rather weak (Son & Anh, 2006).

Given the cost and institutional difficulties in controlling all vegetables, the authorities have preferred to concentrate on the development of a segmented domestic market for safe vegetables, in the expectation that quality development would spread to all chains in the longer run. "This choice represents a shift from a state *command and control* approach towards a stronger reliance on *self-regulatory* or *market-based* approaches" (Hoi, Mol, & Oosterveer, 2009:381). The so-called safe vegetable program was thus launched in 1995 in order to promote IPM practices in combination with the use of low-toxic pesticides. Some communes have been chosen as pilot production regions while a network of safe vegetable stores was established for the distribution of these vegetables. Farmers in selected communes have benefited from considerable support by the MARD in terms of training and technical assistance on IPM, and often inputs and infrastructures (e.g. net house) provision. Currently, the safe vegetable program in Hanoi province covers 2,105 ha (18% of the total vegetable area) and is planned to reach 5,000 to 5,500 ha by 2015 (HPC, 2009).

Moreover, since 1995, individual firms or farmers cooperatives that meet specific conditions and adopt IPM practices, as defined in specific training sessions, have the possibility to obtain the "safe vegetables production" certificate. The certificate is issued by PPD to individual firms or to cooperatives (and not to the single member) and may refer to the whole land or to a specific plot. Issue and renewal (every three years) of the certificate is conditional on the control of chemical and pathogen residues. In May 2009, in Hanoi province, the total certified area amounts to 243 ha while 40 units hold the certificate (33 farmers cooperatives and 7 individual firms). [5]

The market is somehow also reacting to the increasing consumers' demand for safe vegetables and some of its actors began to be more and more interested in guaranteeing the safety of their products. While traditional buyers (mainly local collectors and wholesalers who usually purchase directly from the individual farmers) are not yet much concerned about the safety of vegetables they trade (Hoi, Mol, & Oosterveer, 2009), new players, such as supermarkets, canteens and semi-public companies, are progressively getting engaged in vegetable safety management. These buyers claim to be the most demanding in terms of food safety and the most involved in checking the production process (by field inspections) and the suppliers' product (by laboratory analysis). They mainly purchase through the FOs' management board, often require the certification, and usually pay 20% to 30% (up to 100%) more than the traditional market (Son & Anh, 2006). The demand of those buyers falling short of what is produced in certified areas, a lot of "certified" vegetables are often sold to the traditional market without any premium price.

Vietnam provides an excellent field for studying the conditions of success of collective action in producing and marketing safe vegetables. On the one hand, FOs which have been the main target of public programs for safe vegetables, have proved very responsive in using IPM public training, certification, labeling and communication and in establishing contacts with supermarkets and other demanding outlets for marketing (Moustier *et al.*, 2010). On the other hand, despite more than a decade of considerable efforts by Vietnamese public authorities and market actors to increase the safety of vegetables, the abuse and misuse of pesticides remain a major problem in intensive peri-urban vegetable systems and pesticide residues are source of great concern for consumers. Without denying the benefits of collective action as measured by farmers' income, our study aims at explaining the efficiency of collective action using as a criteria the level of pesticides on the product and as determinants, different sets of variables, internal and external to the FO (such as the group characteristics, the institutional arrangements within the group and the institutional, economic and ecological environment).

4 Conceptual framework, research question and hypotheses

For the purpose of this study, the outcome of collective action is the FO's effectiveness in producing safe vegetables. The collective action problem we refer to is the free riding issue, the opportunistic behavior that might occur when members produce and sell vegetables with excess of pesticides residues, sprayed with forbidden pesticides or harvested without respecting the prescribed pre-harvest interval. When occurring such a case (if detected), buyers or public authorities will suspect the group of not well controlling individuals within the group. The consequence for the FO will be a loss of reputation and possible sanctions like a drop or a stop in the volume to be traded and/or more control of the future transactions and/or administrative fines and/or the withdrawal of the certificate, if any. In Vietnam where most marketing structures have no traceability system at all, sanctions cannot be transferred to the individual farmer and consequences for the group are all the more higher.

Free-riding behavior can emerge as a consequence of the antagonist interest of the farmer and the FO to which he belongs. On the one hand, the individual farmer would act out of self-interest, rationally seeking to maximize his individual gain rather than to achieve the common goal. Hence he would use an amount of pesticide that guarantees higher yield, better looking vegetables, and a relatively inexpensive risk insurance policy against pest attack, without taking into account the possible consequences on the whole FO. The lack of selective incentives within the FO to reward farmers that properly use pesticides and the poor awareness about the risks on their own health, despite the several cases of poisoning of field workers, do not contribute to limit their misuse. On the other hand, the FO is expected to further the interests of its members and, hence, it would aim at producing safe vegetables in order to improve the collective reputation, increase the members' access to more remunerative high value markets and limit the likelihood to be sanctioned by the commercial partners or by the public authorities.

The review of literature suggests that the outcome of collective action depends on at least four factors: (1) the group characteristics; (2) the institutional arrangements within the group; (3) the institutional and economic environment; and (4) the ecological conditions. This study seeks to answer the following question: which is the direction, magnitude, and relative contribution of these factors on the level of vegetables safety?

Based on literature, we have identified a subset a variables for each of the abovementioned factors and will test the following hypotheses.

1. "Group characteristics":

(1.1) Group size: we expect lower level of vegetable safety in larger groups due to higher free riding behavior.

(1.2) Duration of the group: we expect that older FOs produce safer vegetables due to higher level of social capital and, hence, better capacity to cooperate;

(1.3) Kinship: we expect that FOs characterized by higher level of kinship among members present lower free riding and hence produce safer vegetables;

(1.4) Education: we expect to find less pesticide residues in FOs characterized by higher level of members' education;

(1.5) Dependence of members on vegetable production: we expect that the more the vegetable production is salient to the livelihoods of the members, the lower the toxicity level in vegetables because both the farmers and the management board are more likely to be interested in preserving their reputation in the market and the established relations with the commercial partners;

2. "Institutional arrangements":

(2.1) Meetings: we expect that interaction among members may promote the sense of affiliation and the definition of shared norms and, hence, that the higher the number of meetings the lower the free riding and thus the toxicity level in the vegetables;

(2.2) Specific meetings: we expect that the organization of specific meetings on pests and pesticide issues promotes sharing of experiences among members and leads to safer vegetables;

(2.3) Field monitoring effort: we expect that the higher the level of field monitoring effort of the management board, the safer the vegetables; [6]

(2.4) Record keeping of pesticide application: we expect to find safer vegetables if the rules of the FO require members to keep pesticide application records and the management board to perform second-order inspections on the records;

(2.5) Control of pesticides: we expect that the purchase of pesticides by or under the supervision of the management board leads to higher level of safety since type, amount and source of chemicals can be better controlled and specific technical advice can be provided at the time of the purchase;

(2.6) Technical assistance: we expect that the higher the level of technical assistance provided to the members by the management board, the lower the likelihood of pesticide misuse; [7]

3. “Institutional and economic environment”:

(3.1) Support from public authorities: we expect that FOs that have benefited from governmental support in terms of training and technical assistance on IPM are more likely to produce cleaner vegetables;

(3.2) Public threat: we expect that higher pressure exerted by public authorities in charge of conducting field inspections for checking farming practices and possibly of making residue analysis increases the likelihood that FOs produce safer vegetables;

(3.3) Market pressure: we expect that the more a FO directly sells vegetables to high value markets, namely supermarkets, canteens and semi-public companies, the lower the toxicity level found in the produce. On the one hand, these buyers may represent an incentive to keep adequate levels of food safety; on the other hand, they are the most involved in checking the quality of their supplies.

(3.4) Certification: we expect lower toxicity level in FOs holding the certification for safe vegetable production. Firstly, because the certification is prerogative of FOs whose members have attended additional specific training courses on IPM; secondly, because issue and renewal of the certificate is conditional on the control of pesticide residues by public authority, and hence is evidence of past compliance to good agricultural practices in the use of chemicals; thirdly, because water and soil conditions have been controlled; and, finally, because its withdrawal would preclude the possibility to sell to more remunerative markets and hence acts as an incentive to keep adequate safety levels;

4. “Ecological conditions”:

(4.1) Access to groundwater: we expect that the possibility to use groundwater for irrigation increases the likelihood to produce vegetable with lower pesticide residues. According to several studies groundwater is supposed to have lower content of pesticide residues than surface water.

It is worth stressing some noticeable limitations in our study. Although we have considered some contextual factors likely to affect the behavior of the FO’s members, namely the institutional and economic environment, we have included in our analysis only one of the several ecological conditions that can directly influence the toxicity level of the vegetables. For instance, different locations can present an uneven incidence of pests and diseases or be cultivated with crop varieties with a different degree of susceptibility to them. Thus location specificities can lead to different needs to apply pesticides, regardless of the propensity to free ride. Besides, as already mentioned, pesticide residues originate not only from agricultural inputs used by producers, but also from contaminated soil and irrigation water, and hence are not completely ascribable to the farmers' behavior. The impact of these variables may nevertheless be limited by the relative homogeneity in terms of ecological conditions of the research area, situated less than 20 km far from Hanoi centre. Needless to say, if resources had permitted, the collection of more ecological data for every FO would have improved both our analysis and the confidence of our findings. Thus, since, with the exception of access to groundwater, we have considered exclusively the social, economical and organizational structure of the FO and its institutional and economic environment, the proportion of the variance in pesticide residues toxicity which will be explained by the selected variables will necessarily be limited.

5 Data, selected variables and methods

A survey was conducted in June and July 2009 on 60 FOs producing vegetables and located in seven peri-urban districts of Hanoi. [8] The survey was intended to be exhaustive of the 33 certified FOs. It was conducted on 30 of them, three being not available for the interview. The FOs without certification were randomly selected but in such a way that, in each district, certified and non-certified FOs were evenly represented in order to reduce the selection bias due to location specificities. [9]

The survey consisted of two questionnaires: one for FO leaders and one for FO members. FO leaders were asked about members' characteristics and the organization's specificities (history, activities, governance structure, local institutional and economic environment). Particular attention was paid to the different ways to monitor the farmers' agricultural practices related to pesticide use. Responses were triangulated with information collected from the members (three randomly selected members for each FO).

The dependent variable in our model is the average level of toxicity due to the presence of pesticide residues. One hundred and eighty vegetables samples of different crops were collected directly in the field (three samples for each FO). Sampling was done from vegetables that were told to be ready for harvesting and sale to the market, and when the FO had the certificate, from the certified area. Collection was conducted during the hot wet season, in September and October, when farmers face more problems in controlling pests and diseases and when they are likely to apply more pesticides. Due to financial constraints it was not possible to perform gas chromatography-mass spectrometry analysis (GC-MS), an expensive method that would have allowed us to detect the specific compounds within a test sample. An alternative, and cheaper solution, was to rely on the Rapid Bioassay for Pesticide Residues (RBPR) method, a test developed by the Taiwan Agricultural Research Institute. Although not as reliable as GC-MS, the RBPR is considered sensitive enough to meet the FAO–WHO regulations for pesticides in vegetables (Chiu, Kao, & Cheng, 1991). This test assesses the toxicological effect of two common types of insecticides (carbamates and organophosphates) by measuring the percentage of inhibition of the acetylcholinesterase (AChE), a key enzyme in the nervous system of animals. More than 65% of the most dangerous pesticides (i.e., WHO toxicity class I or II) used in the research area belongs to these categories (Bosch *et al.*, 2005). The RBPR is able to measure the toxicological effect but not to distinguish if this is ascribable to the presence of excess of pesticides or to the use of forbidden and extremely toxic pesticide formulations. Because the levels of toxicity have been found not significantly different among the different collected crops, the average level of toxicity for each FO can be calculated as the average result of the laboratory analysis for the three samples. Thus the dependent variable of the model is the level of toxicity proxied by the average percentage of inhibition of the AChE in the three samples (PESTRES).

To explain the observed variation in the level of toxicity in the different FOs we used an ordinary least square (OLS) regression model according to which the toxicity level is a linear function of a set of causal variables and a randomly distributed error term:

$$\text{PESTRES} = \alpha + \beta\,(\text{group characteristics}) + \gamma\,(\text{institutional arrangements})$$
$$+\,\delta\,(\text{institutional and economic environment}) + \eta\,(\text{ecological conditions}) + \varepsilon,\ \varepsilon \sim N\,(0, \sigma^2)$$

The choice to use an OLS model was due to the nature of the dependent variable that is continuous and normally distributed. We used the Breusch–Pagan Test to detect heteroskedasticity and we calculated the Variance Inflation Factor (VIF) to check for multicollinearity. Furthermore, in order to have a deeper understanding of the weight of each factor in determining the vegetables safety, we performed a decomposition of the toxicity level's variance by the statistically significant variables of the regression. Statistical analyses were done by using the STATA 9.0 software.

The sample of 60 observations in this study permits quantitative analysis; however, it does not provide enough degrees of freedom to examine all the factors that have been suggested as influencing the output of collective action. Furthermore certain variables could not be included in the model since they are highly correlated with each other. The independent variables used in the model are described below, with parentheses referring to the coding of the regression variable.

"Group characteristics":

(1) Group size (SIZE) corresponds to the natural logarithm of the number of members in the FO. [10]

(2) Duration (DURATION) refers to the number of years for which the FO has been established.

(3) Level of kinship (KINSHIP) is a dummy variable and is coded as one if all or most members are immediate kin or relatives, otherwise coded as zero.

(4) Education (EDUCAT) is the average number of years the members have attended the school.

(5) Dependence (DEPEND) corresponds to the average share of FO's land allocated to vegetable production in the years 2007 and 2008. As the cropping intensity can considerably vary across the different FOs the measure refers to the land that has been brought under vegetable cultivation at least once during the year.

"Institutional arrangements":

(6) Number of meetings (NMEET) refers to the number of members' meetings organized annually by the management board in order to discuss issues related to production and, possibly, marketing.

(7) Specific meetings (SPECMEET) is a dummy variable and is coded as 1 if the management board has ever organized members' meetings in order to specifically discuss about pests and pesticide issues, otherwise it is coded as zero.

(8) Monitoring effort (MONITOR) is the number of full time field inspectors per hectare of land allocated to vegetable production. The inspectors are in charge of controlling the farmers' compliance to good agricultural practices. Being "Insp" the share of working time dedicated to the inspections of the vegetable fields by each *i* member of the management board, and "ha" the average number of hectares allocated to vegetables in the years 2007 and 2008, the measure is calculated as:

$$\text{MONITOR} = \frac{\sum_{i=1}^{N} Insp_i}{\text{ha}}$$

(9) Record keeping of spraying (RECKEEP) is a dummy variable and is coded as 1 if the FO's staff requires the members to keep record of the pesticide application, otherwise it is coded as zero.

(10) Collective purchase of pesticides (COLLPUR) is a dummy variable and is coded as 1 if the members have the possibility of buying pesticides by or under the supervision of the FO's staff, otherwise it is coded as zero.

(11) Technical assistance (TECHASS) is the number of full time technicians **per** member. These technicians are in charge of providing advice to farmers on good agricultural practices. [11] Being

“Technic” the share of working time dedicated to technical assistance by each *i* member of the management board, and “members” the number of members in the FO, the measure is calculated as follows:

$$\text{TECHASS} = \frac{\sum_{i=1}^{N} Technic_i}{\text{members}}$$

“Institutional and economic environment”:

(12) Safe vegetables program (SVPROG) is a dummy variable and is coded as 1 if the FO has benefited of the safe vegetable program, otherwise it is coded as zero.

(13) Inspections by Plant Protection Department (PPDINSP) corresponds to the average number of annual visits by inspectors of the PPD in 2007 and 2008.

(14) Sales to traditional market (SALETRAD) refers to the average share of vegetables sold by the members in 2007-2008 through the traditional marketing channels, consisting mainly of local collectors, wholesalers and direct sales to consumers. Thus the measure excludes the sales to supermarkets, canteens and semi-public companies and the variable can be considered as a proxy (of the weakness) of the market pressure.

(15) Certification (CERTIF) is a dummy variable and is coded as 1 if the FO has whole or part of land certificated for safe vegetable production, otherwise coded as zero.

(16) Certification * Size (CERTIF*SIZE) is an interaction term built in order to examine whether there are any interaction effects between certification and size.

”Ecological conditions”:

(17) Access to groundwater (GROUNDWATER) is a dummy variable and is coded as 1 if the farmers have the possibility to use groundwater for irrigation, otherwise it is coded as zero.

6 Results and Discussion

In Table 1 we present the basic summary statistics for our variables.

Please insert TABLE 1

The average level of toxicity found in the FOs (PESTRES) is 10.9%, considerably lower than 25%, the level considered still acceptable for human consumption according to the literature on RBPR (Chiu, Kao, & Cheng, 1991). No figure excesses this value but we have to be careful in drawing optimistic conclusions because the variable is calculated as the average level of toxicity found in the three vegetable samples collected in each FO. In fact, looking at the detailed results of the laboratory analysis, we find out that 10 FOs (16.7% of our sample) show a toxicity level beyond the limit for at least one of the three samples collected in each FO. Six percent of samples present excess of toxicity. A first comment is that the figure is not too bad if we consider, for example, that it is estimated that in Europe, a region where technical expertise and quality control is much more developed than in Vietnam, the share of fruit and vegetable samples with pesticides in excess of maximum residue limits is higher than four per cent (EFSA, 2007). A second comment is that FOs present a diversity in terms of level of pesticide residues and that it is interesting to relate it to differences in groups and external conditions faced by those groups.

How do the different causal variables affect the level of toxicity in vegetable samples? In Table 2 we present the results of the regression, namely the coefficients, their standard errors, the *t* values and the statistical significance. The rather good fitness of the regression equation (adjusted-R^2 is 49.35%) entails that, despite the abovementioned limitations of this study, the model is able to explain almost half of the variance thus increasing the confidence in the scope of our findings. Furthermore, in order to have a better understanding of the explanatory power of the different variables, in the right column of the table we present the result of the decomposition of variance by the statistically significant variables of the regression.

Please insert TABLE 2

By grouping the variables in the different sets previously presented we find that the variance breakdown attributes 39% and 36% of the explained variance respectively to the variance of "Group characteristics" and "Institutional arrangements" while "Institutional and economic environment" and "Ecological conditions" respectively explain 13% and 12%. We argue that in our model "internal" features of the organization (group characteristics and institutional arrangements) overweight external forces (institutional, economic and ecological environment) in determining the safety level. Moreover, all sets of considered variables present at least one statistically significant variable.

"Group size" has the greatest impact on the toxicity level. Almost 28% of the explained variance can be attributed to the variance in size but the sign of the relationship does not conform to our hypothesis. Indeed we were expecting more opportunistic behavior, and thus higher pesticide residues, in larger groups. The unexpected negative effect of the group size on the level of toxicity can be explained by suggesting that the impact is more determined by the economy of scale rather than by the free riding. While smaller FOs are supervised by few people working on part-time basis on different tasks, larger FOs present management boards consisting of a greater number of persons and often employ specialized full-time staff. In the latter, it is not rare to find staff, either full-time or part-time, assigned to only one specific duty. Not surprisingly, they present higher level of expertise related to their specific task that can contribute to achieve better results. In particular the presence of qualified technicians and inspectors seems to greatly enhance the likelihood to produce safer vegetables. A further and complementary argument that may explain the effect of group size refers to the different types of farming activity. While in larger FOs the cultivation of vegetables is more intended for subsistence farming and aims at producing different crops to satisfy the family's diet need, smaller (and recently established) FOs are more commercially oriented, focus on the few types of vegetables required by their customers and use a more intensive pattern of production, often without any crop rotation. Therefore smaller FOs are more likely to present a higher incidence of pests and their members more likely to apply more chemical in order to manage pest and ensure better-looking vegetables for the market.

The second factor by magnitude of contribution to the safety level is “technical assistance” provided by the FO’s staff to each member (25% of explained variance). As expected, stronger technical assistance given by the FO’s staff is conducive for achieving higher level of vegetable safety.

“Access to groundwater” for irrigation significantly affects the safety level (12% of explained variance) but with unexpected direction. This finding can be explained by assuming that groundwater is heavily contaminated due to the shallow water table (less than 7-8 meters deep) fed by polluted percolation water. An alternative hypothesis refers to the farmers’ water management practices. According to some information collected during a qualitative survey, irrigation is a time-consuming activity for farmers as they have to move pump, wires and related supports. Instead of pumping a small amount of water every time they need to irrigate their plots, many farmers prefer to save time by pumping more water less frequently and keeping it stagnant in the small ditches along the field. This stagnant water may result with high content of pesticides due to air drift at the time of spraying, presence of empty pesticide containers thrown in the ditches by farmers, and surface runoff of contaminated water.

“Dependence” on vegetables accounts for almost 8% of the variance and, as hypothesized, it is significantly associated to higher safety level. This result is highly consistent with the consensus in the empirical and theoretical literature, validating the hypothesis that members that heavily depend on vegetable production would make greater efforts to produce safer vegetables in order to protect their reputation and possibility to access more remunerative markets.

“Certification”, as expected, is associated with lower residues and explains 7.5% of the variance. Interestingly, the interaction term “Certification * Size” is positively and significantly associated to the level of toxicity. However, as the value of its coefficient is less than the coefficient of group size (in absolute terms), we cannot conclude that, in the case of certified FOs, the level of residues increases as the group size increases, but simply that the positive effect of group size on safety is less pronounced in FOs holding the certificate. [12] Our interpretation is twofold: on the one hand, in large-size certified FOs with more extensive specialized staff, the contribution of this staff to produce safer vegetables is lessened by the fact that farmers have already reached a certain degree of expertise; on the other hand, certification witnesses, whatever the size, a more commercially oriented pattern of production and excludes the hypothesis of low input subsistence farming.

Other variables of the model are still significant but show less explanatory power.

“Education” does not confirm our assumption, higher education level being associated with lower safety. Our result is unexpected since most literature shows that education contributes to limit free riding and to enhance farmers’ capacity to manage IPM practices. We account for the observed relationship by noting that, unlike most developing countries, in Vietnam everyone has at least the basic level of education needed to properly read and understand elementary writing (e.g. pesticide labels or production protocols), and by suggesting that, since there is a negative correlation between level of education and age, the younger may be the ones with less experience in farming and less competence in controlling pest unless using high amount of pesticide.

“Specific meetings” is significant but not in the hypothesized direction. Our interpretation of this finding is that most of these meetings are organized when pests and/or misuses of pesticide are source of great concern within the group.

“Collective purchase of pesticides” conforms to our expectation and is positively associated to vegetable safety, confirming that the greater the control on the type, amount and source of pesticides, the less likely to find vegetables with high toxicity levels. In fact, not only the staff can ensure that only permitted pesticide from reliable sources are used but, moreover, members can receive advice on its proper use by qualified personnel at the time of purchase.

Besides the possibility to purchase pesticides by or under the supervision of the FO's staff, "Record keeping of spraying" confirms that requiring members to keep record of spraying is another effective measure to control their pesticide use and may contribute to achieve higher level of food safety.

No statistically significant effect is found for the two measures of social capital (i.e., level of kinship and duration of the FO), frequency of members' meetings and monitoring effort, as well as for the safe vegetable program, inspections by public authorities, and market pressure..

7 Conclusions

Our paper is an original empirical tentative to explain collective action outcome in the domain of food safety. Through a survey of 60 vegetables growers associations in peri-urban Hanoi and drawing on the common-pool resources management literature, it aims at highlighting the organizational, institutional and environmental conditions enabling successful collective action. Dependent variable is the level of pesticides residues on vegetable samples as measured by a quick test. Explanatory variables include classical group characteristics, the institutional setting within the group and some local external factors influencing group behavior. Our choice of variables has been driven by context specificities and collective action and food safety literature. The econometric model has proved quite relevant since half of the variance is explained, the major contribution coming from group size, technical assistance, salience, certification and ecological conditions.

Our findings shed light on the role of the different sets of factors, among them collective action, in attaining a high level of vegetable safety and, eventually, in giving access to high value safety-demanding markets. First, they suggest that a considerable part of the variance in safety level may be explained by the availability of specific and qualified staff in charge of providing adequate technical advice and monitoring pesticide supply and application. Thus, large FOs seem to be better positioned to properly assist their members while the expected increase of free-riding behavior in larger groups does not seem to be a crucial issue when members are thoroughly supported and monitored. This may suggest that in-house tailor made technical assistance performed on a continuous basis, is a necessary complement to the limited and sporadic good-for-all capacity building sessions given by public programs. It also suggests that, in Vietnam, collective action in the form of technical assistance and IPM inspection is more sensitive to economies of scale than to the free-riding effects that develop in large groups.

Second, our findings highlight the role of certification for small farmers' organizations. Collective action allows small-scale producers to obtain the otherwise inaccessible certificate for safe vegetable production that represents an incentive to limit the misuse of pesticide. In fact, it represents an actual or potential opportunity to sell to more remunerative markets and to build a higher reputation. One finding of our study is that the certificate, far from being an absolute guarantee of safe vegetables, significantly increases the likelihood that vegetables present lower level of pesticide residues, especially in smaller FOs.

Third, the contribution of public authorities to vegetable safety remains controversial. On the one hand, the inspections carried out by public authorities seem to be ineffective probably due to their unreliability, poor accountability and lack of credible sanctions. On the other hand, the establishment of a certification system, that despite its flaws has proved to be a factor leading to safer vegetables, has been a top-down process initiated by the government rather than market-driven. Moreover, the public training programs have increased the level of technical expertise of FO members and leaders, which favors the transfer of technical support in the FOs, with a positive effect on vegetable safety.

Fourth, the contribution of market forces does not seem very salient in promoting vegetable safety. Emerging high value markets have not yet worked as a strong incentive for the adoption of voluntary approaches to manage safety and promote greener vegetables. Despite their claims, demanding retailers are still poorly involved in controlling and supporting their suppliers. Indeed this may reflect either poor willingness to pay for food safety by urban consumers or weak enforcement of food standards and liability rules by public authorities.

Finally, ecological conditions may considerably affect the level of pesticide residues, regardless of the farmers' behavior. According to our findings the source of irrigation water seems to significantly affect the level of residues, but the reasons behind are rather difficult to be appreciated since the effect can be linked either to the quality of the water itself or to the way farmers manage groundwater in their plots.

Understanding the determinants of safer agricultural production requires further investigation that would call for the involvement of soil, water and plant protection specialists. Furthermore this study paves the way to future research that might apply similar methodological approach to a larger sample within or outside the country. Indeed the small sample has prevented us to include more variables in the model and thus to increase the confidence in our findings. It would be also useful to get more economic data on the costs and benefits of reducing the pesticide use. Eventually, it would be interesting to compare collective and individual forms of production organization (e.g. private enterprises), in terms of safety management and performance.

Whatever the continuation to be given to this pioneering work, some preliminary policy recommendations can be formulated on how to promote food safety in vegetable production. While collective action can overcome small farmers' scale diseconomies and considerably improve their effectiveness in producing safer vegetables, the capacity to provide adequate technical assistance and monitoring within the FOs is of overwhelming importance. Public authorities in Vietnam should be particularly concerned about the problem of safety in smaller FOs since they are less endowed with required human resources and more inclined to have intensive pattern of production, due to their strong market-oriented nature. Specific support to increase the effectiveness and capacity of FOs' staff may result in enhanced ability to limit pesticide misuse. The control of the pesticide purchased by the members and the record keeping of spraying increase the likelihood of producing safer vegetables and should be further promoted. The training and technical assistance provided by public authorities should be more consistent and tailor-made according to locally specific conditions and constraints. Finally, public safety regulation should be strengthened and scaled-up, both at the production and marketing levels, either through a more efficient enforcement of process and product safety standards or through the design and management of a more adequate certification system.

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NOTES

[1] In comparison to other safety risks (e.g. pathogen contamination) chemical contamination is even more difficult to be verified by the buyer due to the very low probability of serious and immediate consequences for human health after consumption of fresh produce (Codron, Giraud-Héraud, & Soler, 2005).

[2] The study by Agrawal & Chhatra (2006) represents a noticeable exception.

[3] An exception is Baland and Platteau (1996) who point out that external sanctioning institutions greatly contribute to successful collective action.

[4] Besides acting as a signal for food safety (via a label), the certification may improve the level of the safety (via a standard). Roussel and Mormont (2006) made an interesting contribution on how different certification schemes, and the related different forms of organization and coordination between actors in the chain, can differently affect the farmers' behavior with regard to pesticide use.

[5] The cooperatives holding the certification are only a small part of the total number of agricultural cooperatives in Hanoi province (according to Vietnam Cooperative Alliance they are around 950 but, since there is not a specific record, it is not possible to know the number of cooperatives producing vegetables). Among the cooperatives holding the certification, the share of land certified is highly variable, ranging from 0.5% to 100%. Most of certified cooperatives are located in Dong Anh district, an area highly specialized in vegetable production. The certification has an indicative cost per ha of 10 million VND (around USD 550). In order to cover this cost, the members of FOs cultivating the certified land are often required to pay an annual fee. These farmers organizations are more likely to provide farmers with a written production protocol that the members have usually to sign as proof of formal commitment. Furthermore in most of them a system of gradual

sanctions is in place to deal with violations of the rules (usually going from a warning, to a temporary suspension of sale through the management board, to administrative fine, up to the exclusion from the organization).

[6] The internal monitoring system in FOs can take different forms: it can be undertaken by the members themselves mutually controlling each other; it can be delegated to some hired third-party inspectors; or it can be responsibility of the FO's staff. We have focused only on the latter since the survey could find neither hired external inspectors nor any form of structured mutual monitoring that would allow to be measured by an indicator.

[7] Again, no cases of hired external technicians were found during the survey and thus the focus was exclusively on the assistance provided by the FO's staff.

[8] The seven districts are: Dong Anh, Gia Lam, Soc Son, Thanh Tri, Hoai Duc, Long Bien, and Tu Liem.

[9] The certified cooperatives are not homogeneously distributed across the districts. They are mostly located in the districts with the most favorable conditions for growing vegetables. In such a situation the use of a different sampling method would have prevented us to draw any conclusion about the role of certification in explaining the vegetable safety.

[10] The choice to use the logarithm is due to the fact that the range of size within the sample is rather huge (from 7 to 741 members).

[11] Often, especially in smaller FOs, technical assistance and inspections are somehow overlapping activities. They may be performed by the same persons and, sometimes, even at the same time. In such a case, the field monitoring can be considered more a way to identify mistakes made by the members and to provide technical advise to avoid them, rather then to detect behaviors to be sanctioned.

[12] In certified FOs, group size is still associated to lower toxicity levels: its coefficient is still negative, although considerably lower than in non certified FOs, i.e., -1.24 (-2.93+1.69).

Table 1. *Summary statistics for the variables* (*n = 60*)

Variable	Mean [a]	Standard deviation	Min.	Max.
Dependent variable				
PESTRES	10.91	4.67	2.44	22.49
Group characteristics variables				
SIZE	4.24	1.49	1.95	6.61
DURATION	7.82	3.84	0	13
KINSHIP	16	NA	0	1
EDUCAT	7.18	1.24	5	12
DEPEND	51.42	30.43	2.78	100
Institutional arrangement variables				
NMEET	3.80	3.50	0	16
SPECMEET	27	NA	0	1
MONITOR	0.05	0.08	0	0.41
RECKEEP	9	NA	0	1
COLLPUR	26	NA	0	1
TECHASS	0.01	0.01	0	0.05
Institutional and economic environment variables				
SVPROG	22	NA	0	1
PPDINSP	3.06	3.50	0	21
SALETRAD	83.20	24.14	0	100
CERTIF	30	NA	0	1
CERTIF*SIZE	1.91	2.17	0	6.61
Ecological conditions variable				
GROUNDWATER	11	NA	0	1

[a] For dichotomous variables, the value is the number of positive responses.

Table 2. *OLS regression results for toxicity level and decomposition of variance by the statistically significant variables*

Variable	Coeff.	SE Coeff.	*T*	*P*	Weight (%)
Group characteristics variables					
SIZE	-2.931646	0.680685	-4.31	0.000***	27.8
DURATION	-0.2137657	0.2104034	-1.02	0.315	-
KINSHIP	1.213251	1.118433	1.08	0.284	-
EDUCAT	0.7572012	0.4301875	1.76	0.086*	3.9
DEPEND	-0.0776651	0.01995	-3.89	0.000***	7.7
Institutional arrangement variables					
NMEET	0.1123221	0.1709743	0.66	0.515	-
SPECMEET	2.363918	1.072682	2.2	0.033**	3.8
MONITOR	-7.218534	8.109656	-0.89	0.378	-
RECKEEP	-3.519951	1.754254	-2.01	0.051*	3.2
COLLPUR	-2.426886	1.119497	-2.17	0.036**	3.8
TECHASS	-260.9819	64.0265	-4.08	0.000***	25.1
Institutional and economic environment variables					
SVPROG	1.2353	1.113429	1.11	0.274	-
PPDINSP	0.0412707	0.1653105	0.25	0.804	-
SALETRAD	-0.0387888	0.0233457	-1.66	0.104	-
CERTIF	-9.85929	3.091377	-3.19	0.003***	7.5
CERTIF*SIZE	1.687625	0.7035936	2.4	0.021**	5.2
Ecological conditions variable					
GROUNDWATER	4.910284	1.358841	3.61	0.001***	12.0
Constant	28.65619	0.680685	-4.31	0.000***	

$N = 60$, $R^2 = 63.95\%$, *Adjusted-R2* = 49.35%, $F\,(17{,}42) = 4.38$, Prob > F = 0.0000.

*, ** and *** signify statistical significance at 0.1, 0.05 and 0.01 levels, respectively.

ANOVA: Variance explained by the statistically significant variables = 55.8%.