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Determinants of pesticides reduction in grape growing farms[1]

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Abstract
Mostly determinants of environmental innovations are studied from a general point of view. Yet evolutionist literature shows that the sector is an important variable, particularly studying determinants. This paper works on the determinants of the diffusion of environmental innovation in grape growing as there are not many farms producing grapes with environment-friendly practices. Our main hypothesis is that the features of this agricultural activity (permanent crop, non-point source pollution and agricultural policy) make that theoretical determinants have to be studied in this particular case in order to better understand the diffusion of environmental innovations in grape growing. Then grape growing is often pointed out as using a lot of pesticides compared with other crops. Crop protection is however a critical topic for the protection of the environment. A survey of an innovative way to reduce phytosanitary treatments and also pesticides use in Bordeaux area shows that some determinants have to be discussed. Even if the source of cost savings is real and rather known, it is not enough to adopt this innovation. There are too much organizational pressure and competence needs in adopting such environmental processes and consequently environmental policy does not seem to be strong enough to be a determinant at the moment.

Keys words: environmental innovation, determinants, diffusion, pesticides reduction, grape growing

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Introduction

Recently the goal assigned to the agricultural production has changed because of a strong social demand of environmental protection (Aubertot et al., 2005). Farmers' objective is not to produce lots of products cheaply anymore but they have to conceive green lucrative products. Grape growing is particularly known to consume a lot of pesticides compared with other crops and is considered as a pollutant activity. In spite of farmers' consciousness about the environmental stakes and their efforts, adoption of environmental innovations is too limited. They face a double problem: how to take care about environmental concerns being competitive in the same time? Public research and professional organisms have developed some environmental production processes as organic farming or integrated production but their diffusion is rather slow. Producers haven't enough economic information about these new production processes. The estimated costs of such practices are very high according to the farmers (Saint-Gès, 2006). Consequently they can't detect the potential win-win trajectories described by Porter and van der Linde (1995). Consequently, problems of non-point source pollution and water contamination still remain and it is time to focus on the determinants of the diffusion of environmental innovations in grape growing.

A large part of the innovation theory takes care about the determinants of innovation and about how they are adopted. Mostly determinants of environmental innovations are studied from a general point of view. Yet evolutionary literature shows that the sector is an important variable (Malerba, 2002). This paper aims to show that the theoretical determinants of environmental innovations amongst technology push, demand pull and environmental policy and their role in the diffusion process have to be discussed in the particular case of grape growing. Our main hypothesis is that the features of this agricultural activity (permanent crop, quantities of pesticides used causing non-point source pollution, agricultural policy) influence the diffusion of environmental innovations in wine farms and justify studying its determinants. Are the theoretical determinants relevant for studying grape growing? Are there other determinants? To explore our hypothesis, a survey was made on some grape growers of Bordeaux testing a new way to reduce pesticide use (research program Agriculture and Sustainable Development "Wine and environment"). This study highlights that the role of theoretical determinants have to be discussed in the case of pesticide reduction in grape growing (cost savings for example). Path dependency is rather strong and there are too much organizational pressure and needs of new competences so that present policy could be efficient.

This paper is structured in two sections. In the first one, we examine grape growing features and theoretical elements on environmental innovations to show the interest to have a specific view on environmental innovations in this case. The second part presents the context of the study and its main results. Finally, we discuss around the main determinants influencing the adoption of environmental innovations in grape growing.

I. The diffusion of environmental innovations in grape growing

Social demand and environmental policy are two external pressures leading grapes producers to change their agricultural practices to take into account their impact on the environment. Farms are confronted with a stronger and strong obligation to fit and to adopt environmental innovations. We first show that it is relevant to consider the particular case of grape growing and then we discuss the opportunity of the theoretical elements to study environmental innovations in grape growing.

I.1. Why to be focused on environmental innovation in the particular case of grape growing?

There are several reasons that led us to take interest in environmental innovations in grape growing. First it is a crop really concerned by the environmental stakes because of its strong negative impact on the environment. Then it appears that if some single innovations are adopted, more systemic reasonings are needed now to improve significantly the environmental impact of this production. Finally the features of this activity could require a particular study of the determinants of environmental innovations in grape farms.

I.1.1. Grape growing need of environmental innovations

Amongst the different crops, grape growing is the one which use most of the pesticides used in agriculture (20% on 3.7% of cultivated areas in France in 2005, Aubertot et al., 2005). Most of the impact of grape growing on the environment is due to this consumption of pesticides. First, during a phytosanitary treatment, the main part of the pesticides applied doesn't reach the plant. The chemical molecules pollute the air, the soil or the water. If they are fixed in the soil (where they can stay for decades), they lead to phytotoxicity for young vine plants and to toxicity for fauna. Some molecules as herbicides can also be carried by draining water or streaming water, and are found in all wine basins (IFEN, 2006). Then, the pesticides have an effect on the auxiliary fauna, causing a more and more important need of phytosanitary treatments. Because of these reasons, grape growing is pointed out as a pollutant activity by the experts and the authorities. A demand also comes from the consumers because of the risk to find chemical residues in the wine. Consequently "the Grenelle de l'environnement" planed recently to reduce the consumption of pesticides of 50%. Finally, the simplified technical ways developed these last years (simplification of soil labour or intensive weeding) have made disappear some interesting species as leguminous plants and have caused a destructuralization and the erosion of soils.

These environmental stakes oblige grape farmers to change their technical practices. They must find new ways to produce grapes respecting the environment. Some new technologies and new production processes have been developed. If some single innovations as anti drift nozzles or new equipments have been adopted (Saint-Gès, 2006); it is now necessary to have a more systemic reasoning. Farmers have to consider the global environmental impact of their practices instead of making single improvements. Indeed the environmental performance of grapes production makes sense only considering the entire technical way. For example it seems to be more relevant to try to reduce the use of inputs instead of spraying systematically only trying to limit pollution with equipment limiting the drift. New systemic practices have to be adopted and it requires a new reasoning of production processes. Farms should insert the environmental dimension in a consistent and systemic way. Our hypothesis is consequenly that new production processes are central to take into account environmental concerns in farms and we focus our paper on them. They can be defined as environmental innovations (or eco innovations). The broadly given definition is that environmental innovations are *all measures of relevant actors […] which develop new ideas, behaviour, product and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets* (Rennings, 2000). As the environmental impact is difficult to assess, this type of innovation cannot be defined through their absolute environmental impact but rather in reference to alternative technologies (Oltra, 2008). So we can define new production processes in grape growing as it is done in the larger definition of the MEI report considering that an environmental innovation is *the production, assimilation*

or exploitation of a product, production process, service or management or business methods that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives (MEI Report, 2008).

I.1.2. A lack of diffusion of environmental innovations in grape growing

Actually some environmental production processes exist as organic farming or integrated pest management. But their diffusion is really slow and single in grape growing. There are so few farms producing grapes respecting the principles of organic farming (9% of wines areas being organic or in conversion in France in 2006, *data Agence Bio*). Producers' uncertainty about the technical and economic results of environmental production processes is important and seems to limit their adoption (Saint-Gès and Belis-Bergouignan, 2007). Consequences of the adoption of such innovations are unforeseen as much as the technical consequences (on yield particularly) and the economic consequences (additional costs, organizational pressures, etc.) are unknown. Besides Pailler and Corade (2004) have shown that having no information about the impact of a technical modification on the economic balance of the farm is the main reason why the farmers are reticent to change their practices. Uncertainty is radical because farmers are not able to identify correctly the risks taken when they modify their production process. They necessary look for the combination about environmental and economic performances and they are afraid that changing their practices can be synonymous of additional costs (Saint-Gès, 2006). According to them, the economic viability of environmental process innovations is not demonstrated. They receive a risk in term of economic impact on the farm structure. Consequently, the diffusion of environmental processes is slowed down in grape growing.

Producers dislike risk for several reasons: they are looking for economic stability; the past incentives to improve yield; the previous failures in vineyard protection; the present economic crisis in wine. They are consequently reticent in change of technological trajectory as tey can't detect relevant ones. They are locked in the routine of intensive production. Intensive production is the dominant design of current viticulture, commonly called conventional viticulture. Conventional grape growers are in routine regime as described by Winter (1984) as much as there are a lot of important limits to the adoption of new environmental processes despite they exist and so to change this regime. These unusual processes for conventional grape growers require a learning process to acquire new knowledge and competences. They also have to arrest new organizational modes and reasoning methods to achieve their implementation successfully.

I.1.3. Innovation in grape growing: elements of an intra sectoral analysis

Mostly environmental innovations are studied from a general point of view, whatever the industrial sector. The level of analysis is rarely discussed (Oltra, 2008). Yet evolutionary literature shows that the sector is an important variable (Malerba, 2002). Some characteristics of different sectors make the innovation process can vary from a sector to another. Possas et al. (1996) precise that *sector specific, firm specific and even institution specific features should receive great emphasis, even more than generic ones*. Agriculture is classified by Pavitt (1984) as a *supplier dominated* sector. This sector is presented as having a very low degree of concentration, product homogeneity, a strong competition about prices, low rates of technical change and a limited innovation capacity by its own. Consequently agricultural

innovation is often studied in upstream industries as pesticides and fertilizers industries. Agriculture has some specific features (Possas et al., 1996):

- Production strongly depends on natural conditions and the biological cycle is long. The climate and the local conditions of cultivation are particularly involved in the need of crop protection,
- Sources of cost savings are very limited,
- Size and organizational of productive farms vary widely,
- Its degree of technological appropriability is low.

In addition adoption of environmental innovations at farm level is rarely studied. Yet the producers are the central actor in the decision to innovate adopting environmental production processes.

Grape growing is a permanent crop. Compared with other crops it necessities more phytosanitary treatments per surface unit. Indeed the crop is not destructed once a year what eliminate the potential sources of contamination and there is no crop rotation on the plots. In grape growing potential sources of contamination exist as soon as the beginning of the cultural year. These sources can't be identified and are only evaluated. Because there is a strong possibility to fail, farmers spray as soon as the meteorological conditions are favourable to fungi (whether there is or not sources of contamination). In the same way the evolution of these sources can't be described precisely, here again it is evaluated. These reasons explain that farmers don't want to take a risk and that the number of phytosanitary treatments is very high. Because it is concentrated in time and space and following these numerous treatments, this activity has a strong impact on environment. Because they are caused by a lot of individual firms, the damages caused at the environment in agriculture are characterised by being a non-point source pollution on large scales and areas; they are continuous even if they are unpredictable, interdependent and cumulative (Le Clech, 1995). It is therefore impossible to link up pollution to the farm which caused it.

Finally, we have to notice that public policies and public institutions (taking a large part of the subsidies for research) are very present in this activity. If grape growing is not concerned by past incentives to produce of the European Agricultural Policy, it is a regulated activity (yield, prices sometimes and regulations). Concerning subsidies we have to notice that some of the agro-environmental measures contained in the last reform of the European Policy concerned grape growing. They consisted in a subsidy for farmers having some environmental practices. It appears that it was not very successful. A better understanding of the features of this activity should help us to identify the determinants of the adoption of environmental innovation in grape growing and consequently should lead us to suggest some new adapted policy schemes.

I.2. Are theoretical determinants relevant for the diffusion of environmental innovations in grape growing?

General innovation theory traditionally distinguishes technology push, demand pull and the market as relevant determinants of innovation activities. In the case of environmental innovations these determinants have to be completed by the strong influence of environmental policies (Cleff and Rennings, 2000).

I.2.1. Technology push

Technology push determinants emphasize the individual capacity of a firm to innovate. Attention is turned here on the capabilities of a firm in terms of technology and knowledge to develop or adopt innovations. The theory underlines that path dependency is really important in innovation activities, and also that *innovation breeds innovation* (Baumol, 2002). As it is described by Pavitt (1984) low rates of technical change and a limited capacity of innovating by its own characterised the agricultural sector and grape growing as a part of it. There is an important tradition of habits in this sector explaining a part of the lack of environmental innovations in grape growing.

Then a firm is encouraged to innovate only if it makes sense for it (Horbach, 2008). It depends on the appropriation capacity of the firm. In the case of grape growing, we see before that the capacity of the farmers to identify the potential profits associated to environmental innovations is more than limited. A large part of them think that additional costs are necessarily the consequence of environmental innovations. It is linked to their dependence to their path, because the large part of the past single innovations adopted were more expensive and restricting ones (new nozzles, new active ingredients, premises for pesticides, areas to wash the sprayer, etc.). So they have the same feeling about environmental processes and hesitate to adopt them.

I.2.2. Demand pull

The demand from consumers or from other firms is rather important in the diffusion phase of innovation (Pavitt, 1984), particularly for environmental innovations. Farmers have no interest to develop new production processes if the consumers don't want to. We emphasize before that there is a real demand about environmental care from the consumers. Wine as a relative good image compared with other food products. It is associated to luxury and should ever respect the environment according to the consumers. So this demand doesn't influence the producers as much as it seems that consumers are not ready to pay more for it. According to them, it should be a characteristic of such a product. In this context, farmers' efforts are minimum trying to respect the environmental regulation (image, marketing) and are not ready to do more.

I.2.3. Environmental policy

More than concerning other innovations the market is inefficient for environmental innovations because of the external negative effects associated. Therefore having an environmental policy is necessary to encourage innovation. Porter and van der Linde (1996) postulates that the firm dont' detect the potential of environmental innovation because it is impossible for it having no experience dealing with such problems and because it misses information, knowledge and competences, organizational ones for example. They particularly emphasize that the firm is not able to recognize the cost saving potentials of such innovations, what it is true for grape growing as much as the farmers have no economic information about the innovations proposed. So the famous hypothesis of these authors is that *environmental regulation may lead to a win-win situation so that pollution is reduced and profits are increased* (Horbach, 2008). The offsets of regulation are rendered by benefit of productivity for innovation processes and by quality improvement concerning product offsets (Porter and van der Linde, 1996). In grape growing, the adoption of environmental processes of production is rather more complicated because some examples show that environmental

processes as organic farming can suffer from less productivity (yield) and that it can lead to a improvement of wine quality (less pesticides residues in wine) despite it is a process nor product innovation.

As it is underlined by Rennings (2000), environmental policy should have a *regulatory push-pull effect*. It is no so simple in the case of grape growing. Because of the type of pollution (non-point source) it is rather difficult to have an efficient regulation compared with other industries. In chemical industry, norms (emission level) have been adopted to limit the emissions of firms and these emissions can be controlled rather easily. Non-point source pollution can't be controlled so easily and even when the measurement of this pollution is possible (in rivers for example) the chemical molecules found can't be linked to a single farm. It is very difficult to know the part of each farm in the pollution. As an indirect way to identify the behaviour of farms toward the environment some regulations were set up as the obligation to record every spraying practice on the vineyard, based on the supposed link between the practices and their impact on the environment. But it is now impossible to control all these registrations and a field experience shows that it is not efficient. In the same way all the environmental regulations concerning grape growing are not very coercive and rather not completely respected.

Consequently, policy instruments don't create the highest incentive to innovate. Environmental innovations are certainly the result of a more complex process in grape growing. So the next part focus on the particular case of the adoption of an environmental innovation in grape growing in order to illustrate the question and to show how the innovation theory highlights the process but doesn't take all the relevant elements into account.

II. The study of an environmental process innovation in grape growing and discussion around its determinants

The adoption of an environmental process innovation has been tested during the research program ADD (Agriculture and Sustainable Development "Wine and environment" 2005-2008). The different work packages lead us to identify potential cost savings and to have a first approach to the driving forces of environmental innovations in grape growing. We present this innovation, Mildium® and the results about costs. Then we discuss about the determinants of pesticides reduction in grape growing.

II. 1. Mildium®: a new way to reduce pesticide use

The ADD research program lies in the hypothesis that possibilities to improve the environmental performance of grape farms exist and are compatible with basic economic imperatives for the management of farms, especially concerning pesticides use. Because of the important use of chemical inputs we choose to study a new pesticide reduction process (Mildium®). We present it and the economic result of his adoption taking a special care to the cost saving potential, as previous additional costs have been identified by farmers as the main limit to adopt environmental innovations in grape growing (Saint-Gès, 2006).

II.1.1. Presentation of Mildium®

The research work was led by research teams from different disciplines and focus on the goal to reduce the number of phytosanitary treatments in grape growing (especially

concerning mildiou and oïdium, diseases generating most of phytosanitary treatments in grape growing). The method tested is Mildium®, a new rule to decide triggering off a phytosanitary treatment and was developed by INRA. The ambition is to achieve a satisfactory level of vineyard protection securing the quality and the quantity of harvest with a limited number of phytosanitary treatments. The rule is based on specific observations of the vineyard in the field compared with meteorological data and with local data about the contaminations in the way to reason the best and appropriate moment to trigger off treatments against mildiou and oïdium (Léger et al., 2007).

Using this rule modify fundamentally the way the producers reason their vineyard protection, usually based on the reasoning of the date of the first treatment and then spraying always with the same cadence (nearly every fourteen days). Consequently it is a new protection process for grape farmers. The technology used for spraying is the same (and should be as better as possible) however the vineyard observations necessary to trigger off spraying require to acquire new knowledge and competences, especially to identify oïdium at the early beginning of the disease. During the test, the decision of spraying was taken by researchers to secure the production (first year of the test) but it necessities also experience to take the right decision. These observations also lead to a re-organization of the cultural planning as much as phytosanitary treatments are no more programmed automatically and are in competition with other operations. Despite of the technical precautions taken during the test, the risk associated to this rule estimated by the farmers is very high. Mildium® seems to be an environmental innovation with an important uncertainty.

II.1.2. Method: measurement of innovations and limits for grape growing

Studying innovation in firms is not an easy task because data bases were not made for it until now. The traditional variables used to study innovation efforts in firms are patents and Research and Development (R&D) expenses (Bouba Olga, 2003). They are rather not adapted to study innovation in grape growing farms. According to Possas et al. (1996) agriculture is indeed a sector with low rates of change and has a very limited capacity to innovate. It is clear that innovation by its own is complicated for this type of firm particularly according to the small average size of the farms. Because of this reason research and development activities are insignificant and the expenses can't be isolated or identified when they exist. In the general innovation theory, the effect of the firm's size on innovation activities is undetermined but it is easy to understand that such small sized firms don't really have the possibility to innovate because of a lot of fixed charges to support. Patents are also very rare in farms. As we say before, technical change traditionally comes from upstream industries and is often technological change (pesticides, seeds, fertilizers and farm machinery). Finally agricultural data bases are rather poor concerning innovation in farms, perhaps because their proneness to innovate is rather low and because it is difficult to measure it having no adapted indicators. Consequently we first propose to calculate the cost of this new process. In the aim to bring an answer about the consequence of Mildium® on the costs, a method of management accounting has been set up and adapted from ABC[2] because such detailed costs have only be given from experts and show a important variability. This method allows calculating the cost of phytosanitary protection on farms. Then other points were approached by inquiry or recording of the farmers' practices.

[2] Activity Based Costing

II.1.3. Results: highlighting potential cost savings

Although this study concerns a few grape farms[3] in Bordeaux[4] area it allows to have an interesting though about the economic, agronomical and pathological consequences of the adoption of a new decision rule for spraying (Mildium®) tested on a plot of each farm thanks to the collection of many information about the farms. Concerning the potential economic consequences of the adoption of this vineyard protection process the risk is important as it is a major innovation for the farmers. Because the technological regime has a founding effect on the organization of the firm and its evolution a production process change is at least partially linked to organizational innovation in the firm. The adoption of such protection process leads indeed to the need of new organizational methods in the farm. Reasoning the protection process differently have an impact on the organization of others cultural operations. This innovation also belongs to radical innovations and is supposed to have important economic consequences for the farm (Freeman, 1992). Mildium® requires in addition new and radical knowledge and competences compared with the ones available in the farm. Finally it seems that this innovation constitutes a risk for the farm because it challenges organizational and production habits.

This type of innovation can modify the economic balance of farms (decreasing yields and quality of harvest, investments, rise of production costs). This new decision process implies a different combination of production factors compared with the classical technical way. On the other hand if it doesn't require financial investments in new equipments because the practices are modified with a constant farm structure, it requires a personal investment to acquire new knowledge and competences. Only the production costs could be modified following the adoption of Mildium®. It is a really important consequence because costs are rather the only lever for grape farm management as much as prices and yield are nearly fixed in *appellation* regime.

The economic consequences on the cost have been evaluated calculating the difference between the cost of the traditional protection and the cost of Mildium®. If the decision rule allows farmers to reduce their pesticides use until 60% depending the years, the cost reduction associated is lesser. Indeed the major part of the cost is constituted by fixed costs as material and equipments. 2007 (a year with important disease pressures) the average benefit is around 82€ per hectare essentially constituted by product use reduction when the traditional protection cost is about 519€ per hectare (except Botrytis). Here we show that potential cost savings exist in adopting Mildium®. However a survey of the farmers after two years testing the rule show that they estimate that this cost saving is not important enough to compensate for the risk taken in terms of quantity and quality of the harvest. The farmers questioned argue that cost saving is not a choice criteria for them concerning vine protection.

II.1.4. Other elements about pesticide reduction in grape growing

Calculated costs don't take into account the necessary observations to trigger off the decision to spray. These observations have been realised by the scientists. However the

[3] Because of the difficulty to measure the consequences of the adoption of an environmental process on one hand (necessity to collect a lot of very precise information) and in the aim to identify relevant work packages for the next research program with more farms (A2PV 2008-2011) on the other hand we make he choice to work on few farms.

[4] The Bordeaux vineyard stretch on about 124 800 ha and count around 9 000 farms and including 57 different appellations.

previous entire adoption of the rule by the farmers on their own, we have to explore the conditions of its entire appropriation by the farmers. For the grape growers these observations imply:

- A personal investment to acquire new knowledge (for the identification of early oïdium for example) and assessment to know when to trigger off a phytosanitary treatment according to the different information available in the rule (results of the specific observations of the vineyard in the field, meteorological data and local data about contaminations),
- An organizational investment as much as observations have to be well positioned in the technical way and as the protection process change has an impact on the others operations,
- A modification of the farm routines, particularly in the decision process.

These sides of practice change are the real main limits to the potential adoption of Mildium® on grape growing farms according to all the questioned farmers. Besides a larger survey[5] about the determinants of pesticides reduction realised during the same research program show that they are locked in a conventional viticulture and that it is more due to the fear from diseases (consecutively to past bad experiences), path dependency and competences problem than to the potential cost of new practices (Marandet, 2007). The protection goal is consequently they want to see no symptom on the vineyard whatever the necessary practices because wine growing is a cash crop and implies high returns from pesticides use. Even if some disease spots are accepted *a posteriori*, one of the major limits lies in the goal protection of the farmers. They absolutely reduce the risk, especially because yields are restricted in *appellation* regime.

The main part of Bordeaux grape growers asserts that some observations are ever realised in the vineyard (Marandet, 2007). Yet these observations are only marginal and for the main part are realised to confirm a decision and to verify treatments efficiency. They consequently don't take part to the decision process to trigger off a phytosanitary treatment. The observations for Mildium® have to be made earlier and more specifically. Even if the farmers have a lot of available information (wine magazines, varied news bulletins), this information can't be the only support of a practice change because they are too general and the information necessary to modify the practices mainly lies in tacit knowledge. The only environmental innovations well accepted by the farmers are the ones with a risk as low as possible (coming in general from upstream industries).

Grape farmers don't seem to be ready to get involved alone in such a step because of the opportunity cost. They haven't enough time to acquire new knowledge and competences and above all because they are afraid from protection failures. The choices made in routine practices show that vineyard observations are no priority for them. There is now a risk to let the farmers apply this new protection process alone because they don't seem to be ready to give the right place to the observations in a time pressure situation having many other operations to realize in the same period. This choice will then be very dangerous for vineyard protection with all economic consequences associated (relegation of some plots, decreasing yields). Innovation capacity of the farmers is also limited by the routines of the farm: superficial observations to verify the result of the vineyard protection applied, too much varied information, bad interpretation of available information (always leading to spray) and very important aversion to economic and technical risk. Because of this last point (risk

[5] Survey on 119 farms representatives of Bordeaux vineyard, 2007.

aversion), it can be expected that the grape growers will probably stay in their conventional paradigm rather than changing their practices because the solutions for vineyard protection are easier and well-known what is reassuring for them.

II.2. Return on theoretical concepts

II.2.1. No win-win trajectory in grape growing ?

The previous results show that as it is largely demonstrated in theoretical literature the producers have little interest to adopt environmental innovation. It is an important pressure for them because they have the feeling to take a big risk for the vineyard protection (despite the good economic and technical results of the test they don't feel secure) and it necessities new knowledge and competences. They have in addition little advantages to adopt this innovation because the main effect (reducing the negative environmental impact of the farm) is positive, socially desirable and benefits a large public. But:

- As the consumers and other buyers don't seem to be ready to pay more for environmental wine (there are also some doubts about quality taste of environmental wine according to some consumers),
- As there is no expected productivity improvement,
- As the cost saving potential of Mildium® (or others methods for pesticide reduction in general) are not sufficient to compensate for the risk,

farmers don't detect any private return. It can be expected that only farmers with a strong environmental consciousness will adopt such protection processes. But it is not enough to reduce the impact of this activity on the environment. There is a market failure, linked to the double externality problem described by Rennings (2000) which causes a lack of private incentives leading farms to under-adopt environmental innovations. According to the same author, it should justify the needs of policy instruments and the fact that these instruments are the main determinant of environmental innovations.

The present regulation is not strong enough to encourage the adoption of environmental processes. A reduction of 50% of pesticides was announced by the government for next years but without clear explanations about the modalities. We suppose that it will be difficult to find a regulation adapted to the case of this activity. Amongst the different instruments to reduce pesticide use studied (tax, book of specifications, product differentiation, ambient tax, quota system), a differentiated tax appears as the main solution. But at the moment farmers assume that the price of the products is not the first criteria to choose their protection way. Consequently the impact of such a regulation will lie in the importance of the tax. A tax might be environmentally ineffective for low levels (Deola and Fleckinger, 2008). Indeed this solution doesn't take into account the pesticides industry lobbying. The farmers finally doubt finding private returns compared with their present situation in adopting environmental processes as it should be the case according to Porter and van der Linde hypothesis (1995). They argue that a tax let them only two choices:

- Taking an important risk in their protection process with expected serious protection failures without cost savings because of the increasing prices of the products used,
- Having increasing production costs.

But some new processes as Mildium® will then be interesting to fulfil the protection objectives without increasing production costs.

II.2.2. What about involving the collective dimension of wine sector?

Environmental innovation is the result of compromises between various determinants and objectives (Oltra, 2008). As it seems that environmental policy and demand side could have little influence on the adoption of environmental innovation in grape growing, we take attention to some supply side determinants. We previously show that cost savings and productivity improvements are not expected but networking activities and supply chain pressure can be an interesting way to encourage the adoption of environmental innovation in grape growing. Indeed, viticulture concerns a lot of actors interacting on a territory with upstream structures (sellers of phytosanitary products) and downstream ones (traders for example). There are also wine professional organisms, technical institutes, research centres, wine labour unions and wine cooperatives structuring the territory and the wine sector.

Further to this survey and many discussions with the farmers we make the hypothesis that the existing relationship between the different actors may be a determinant to adopt environmental processes. As a matter of fact farms with a large network could work together with other actors and make the pressure decrease sharing the constraints and improving their innovation capacity by this way. So the main limits to the adoption of a process like Mildium® (necessity of new knowledge and competences, risk aversion) can be exceed. Some actors of wine networks as the cooperatives ever have some interesting knowledge and competences. For example, cooperatives technicians know their territory very well. They ever assume a technical coordination between the farmers, especially about phytosanitary questions and they have a direct relation with the producers (face to face). They have the capacity to choose the right plots representative of a micro area. It would also reduce the quantity of necessary observations on each farm. In addition they ever have the competence to make the necessary observations. They require a lot of time but it is included in theses technicians' missions (as for other local wine organisms). Finally they are expert to trigger off treatments even if they traditionally use other more incomplete rules. They only have to train in order to master Mildium®. They consequently have a better capacity of appropriation than farmers and we notice during the research program that a lot of local wine organisms had a strong interest in this vineyard protection process.

It is of course not to say that all the process should be assumed by technicians. It could be interpreted as a self-regulation of pesticide use by the professionals. But the pressure linked to Mildium® can be pooled at a collective level to close the limits of environmental innovations. We consequently suppose that the innovation capacity of a farm strongly depends on its organisational routines. So a farm with an important and relevant networks (rather local ones because of the necessity to know the territory very well and to train the farmers during the process). We expect that the process could be decomposed in two parts:

- First farmers and local wine organism leading the process together,
- Then the operational phase assume by farmers.

Being involved in all the process phases improves the individual innovation capacity of farmers (learning by interacting). Learning processes would be collective ones and farmers could learn not only from their previous experiences but also from other farmers and technicians to exceed the pressures linked to such environmental processes. It is particularly true in the case of cooperatives because farmers form the collective themselves allowing them a better appropriation of this method, of their territory and to master new complex practices developing cognitive mastery (Filippi and Triboulet, 2006; Capitaine et al., 2008).

The survey of Mildium® in grape farms confirms that even if they have developed an environmental consciousness such firms have a very low capacity to adopt innovations. We showed that theoretical determinants as cost savings and environmental policy are not relevant today for pesticides reduction but that an important thing to favour innovation in grape farms is to combine the existing tools (policy) with the collective dimension to activate regulations.

Conclusion

Studying economic and environmental dimensions of farms simultaneously have little been explored until now. However the proposition of new environmental practices has to come with methods measuring their opportunity. Because of its strong impact on the environment grape growing is particularly concerned by the environmental dimension. Within this framework the paper shows that grape growing has some features calling into question the traditional determinants of environmental innovations. It seems that demand pull and particularly environmental policy are not so strong for grape growing than it could be according to general innovation theory. We mobilize some papers of evolutionary literature and grape growing features to show how it is interesting to focus on environmental innovations especially in this case.

In order to show it in a first attempt we analyzed the set up if an environmental process innovation, Mildium®. Considering the pesticides consumption of grape growing in regards to other crops, it is relevant to focus on this new vineyard protection process. We first took interest in its consequences on the practices costs as it was identified as the main limit to the adoption of environmental innovation in grape growing. First results showed on one hand that there is no additional cost and on the other hand that the true limits to adoption of environmental innovations lies in a lack of knowledge, competences and organisation necessary to set up such practices. Consequently the risk aversion of farmers is very strong and they are locked in their trajectory. Then the individual innovation capacity of farmers being very limited we explore two hypotheses to encourage the adoption of such processes. First we consider the possibility of a tax on pesticides without being sure it could be applied quickly, and then we consider the interest to mobilize wine local actors to improve innovation capacity of farmers. These actors could cooperate to combine the operational spraying by farmers to a management of the process shared between farmers and local wine technicians. It would constitute a management of innovation system encouraging the diffusion of environmental innovations in grape growing limiting the economic and technical risks. The most effective way to sustain production in the long run and to limit pesticide use is finally perhaps to combine regulation instruments with the action of professional organizations.

So this paper suggests a first attempt to the determinants of the diffusion of environmental innovations in grape growing. Underlining the features of this activity shows interesting results and also the necessity to go further into the question in order to explore the influence of the different determinants on the capacity of grape farms to adopt environmental innovation combining productive efficiency and product quality.

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