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ORIGINAL RESEARCH ARTICLE

On the possible impacts of a regulatory change on resource conservation: The case of the plumpox virus in France

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ABSTRACT

Preserving natural resources in the context of global change includes looking at how to protect trees, whether in forests or for fruit production, from various epidemic diseases. A change in European regulation presently underway (EU 2016/2031; currently, in 2023, transitional measures are being implemented in France) transfers, from the public authorities to the profession (all the tree growers susceptible to be concerned), the responsibility for detecting plum pox virus, which has the potential to damage virtually all stone fruit orchards, and for eliminating the affected trees. Yet the disease is a viral one, transmitted by a vector (aphids) from tree to tree and from orchard to orchard. Within a few years, fruit from contaminated trees can no longer be marketed. We show here that, in the context of this new regulation, the heterogeneity of the tree growers (due to the size of the orchards, the diversification of the crops, the future of the farm...) can lead to a recrudescence of the disease throughout the stone fruit orchards. This would also imply all kind of negative effects on the economic (employment in the agricultural sector, national trade balance, processing and marketing sector activities...), social and environmental (landscapes...) levels. The results can easily be generalised to any problem of conservation of natural resources whose management is delegated to private stakeholders.

Keywords: tree pathologies; tree protection; global change; risk; regulation; economic incentives; game theory; mechanism design; economic modelling; heterogeneity

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1. Introduction

The conservation of natural resources must be considered in the new context of global change, including, for example, climate change, economic change (internationalisation of trade), new epidemic risks, and regulatory evolutions. Trees, whether in forests or destined for fruit production, must be the focus of particular attention, because of their long-life cycle or production cycle. In this article, we show how a simple regulatory change can jeopardise an entire production chain when natural resources are not preserved.

The example we are working on here is plum pox (also known as sharka), a disease affecting fruit trees. It is an incurable viral disease of trees of the genus Prunus (apricot, peach, plum, mirabelle, etc.)[1]. It spreads from tree to tree and from orchard to orchard[2] (see in **Figure 1**, how the orchards might be closely interlinked) and is transmitted by aphids[3]. It can also originate from the installation of contaminated plant material. It occurs on almost all continents, possibly with different viral strains[4,5], and does not affect human or animal health if infected fruit is consumed. However, it makes the fruit unmarketable due to its bitterness or acidity, once the disease is well established in the tree (which can take up to 6 years). It is therefore one of the most important viral diseases that can affect food production[6]. Before this happens, the visual appearance of the fruit is damaged (see **Figures 2** and **3**), but it remains valuable for processing (jam, juice, etc.)[7]. Control measures consist in the identification of affected trees (first visually, see **Figure 4**, then with possible confirmation by sampling and laboratory testing) and their uprooting[8]. In 2020, 32,000 trees were found to be infected with sharka in the French region of Occitanie[7]. The use of insecticides to control the vectors of this disease has proved ineffective[9].

Figure 1. Example of closely interlinked orchards in the South of France.
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Figure 2. Sharka virus symptoms on apricots.
Source: © INRAE ROUGIER Jacques.

Figure 3. Sharka virus symptoms on peaches.
Source: © INRAE DUNEZ Jean.

Figure 4. Plum pox virus symptoms on apricot foliage.
Source: © INRAE RAVELONANDRO Michel.

The control of this disease is complex due to recent regulatory developments, which we will outline below. Transitional measures are underway, while the full regulatory dynamics are not known to all stakeholders[7].

The uprooting of trees causes losses that are all the more serious because arboriculture requires an initial investment, while several years are needed to bring the trees into production. Then comes a production period, which itself takes a different length of time depending on the species. This involves an additional complication of decisions at the level of each tree grower, which is very similar to that found in the silviculture of trees in forests when the trees are well managed: coordination between the different plots, delay effect, discounting effect, search for overall profitability and viability, adaptation to different types of risk, etc.[10–13]. This means that the losses resulting from the uprooting of a tree or a plot are multiple. They include, for example, the imbalance in the management of the orchard as a whole[12]. It may therefore be all the more tempting for a grower to postpone uprooting, especially if it involves an entire plot, in order to market his production for a few more years. The same applies if he intends to give up this activity in the following years, for example by retiring.

Overall, the control measures taken so far have proved effective, within the current regulatory framework, by coordinating and financing, under certain conditions, the detection and uprooting of affected trees or even entire plots (when more than 10% of the trees are affected): between 2014 and 2019, the number of infected trees has decreased in France[14].

A new European Union regulation (EU 2016/2031)[15], which aims to harmonise plant pest control at the EU level, has changed the classification of plum pox. In short, funding for the control of plum pox will now mainly be the responsibility of the professionals directly involved, rather than of the public authorities. In 2000, plum pox was classified as a 'quarantine pest' (QP; Directive 2000/29/EC)[16] and was subject to compulsory control. We will not describe here the complexity of the organisation of the control (interested readers are referred to Mellin[7]), with the definition of different enhanced surveillance zones, when an infected tree was detected. Since the new EU regulation of 2016, plum pox is no longer considered a QP, but a 'regulated non-quarantine pest' (RNQP).

The new regulation[17] considers that plum pox (or sharka) is now widespread in the European Union and that it would be unrealistic to aim for its eradication. EU compensation for eradication, which was 100% for QP, is limited to 75% for RNQP, but additional national compensation is allowed. The French government has also introduced transitional measures (until 2024). Overall, the French state wants to withdraw and is asking professionals to organise themselves in order to continue. The option currently under consideration is the possible creation of a PSIC (French acronym for Community Health Programme: Programme Sanitaire d'Intérêt Collectif), which would allow the French government to co-finance certain actions and to compensate tree growers for some of these actions. We show here how important it is to set up this type of control organisation, whatever form it takes, but which could allow tree growers to be compensated for the costs of detection and uprooting.

We will explain why it is important that the fight against the disease continues to be organised at the broadest possible level (geographically, by involving as many professional and amateur tree growers as possible, but also in terms of the species and varieties susceptible to the disease). Otherwise, this regulatory change could lead to a resurgence of the pathology: as we have seen, tree growers are indeed very heterogeneous, ranging from the amateur with a few trees to the professional integrated into processing or marketing networks. They all act according to their level of information, the area under threat, their income, assets, objectives and constraints, level of financial debt, personal aspirations (such as succession or early retirement), and so on. This means that their interests in combating this pathology are very diverse. An indirect consequence is that the coordination of control measures becomes more difficult, since they are not necessarily in everyone's interest. It is certainly not possible to model all this complexity[18,19]. Modelling consists of making choices to focus on the essential aspects of the problem being addressed, in this case the organisation and interest of compensating tree growers for their control efforts to detect the disease and uproot affected trees.

By making the effort to detect and control the disease in his or her orchard(s), each tree grower modifies the risk of the disease spreading to neighbouring orchards. This is a positive externality and, without concerted action, classical economics shows that the overall effort will remain sub-optimal[20], which is all the more plausible given the heterogeneity of tree growers.

We also understand that if the costs and interests of each tree grower differ from each other, they also differ from the interests of the profession as a whole (which suffers directly from the effects of the externalities presented above, in particular the spread of the disease, but also from the securing or not of the supply of production chains from which everyone benefits)[21]. They also differ from the interests of the State (which is not insensitive to employment, the quality and quantity of production, national food security, the balance of trade, tax revenues and, more generally, the social, environmental and economic impact of this production)[22]. It is by taking into account these three different levels (the grower / all growers / the State)[23] that we can better anticipate the impact of ongoing regulatory changes, possible corrective mechanisms[24], or new, more effective control strategies. Ultimately, the withdrawal of the State from the control of this disease could have as its main effect an increase in the spread of the virus and a significant reduction in production, with all the associated consequences we have seen.

Depending on the regulations in force, there may also be a problem of asymmetric information. In principle, the grower is obliged to declare the presence of the disease. However, there are two problems: on the one hand, the difficulty of detecting it, possibly due to a lack of knowledge, especially among non-professionals (which is why the mission of FREDON, a French organisation that brings together a group of regional pest control structures, is essential). On the other hand, tree growers may discover the presence of the disease and destroy some of the affected trees without declaring it, for fear of exceeding the 10% threshold that would lead to the destruction of the plot, as the regulations currently stipulate.

In the remainder of this paper, Section 2, we set up a model that highlights the difference in interests between 1—individual tree growers, 2—all tree growers and 3—the State. Section 3 introduces the positive externalities of disease control: each control benefits the tree grower who carries it out, but also indirectly benefits all others by preventing the spread of the disease. We then show the advantages of forming the largest possible association, hereafter referred to as a 'group', to fight together. Section 4 examines whether, once such a group has been formed, it is worthwhile for a grower to join it or not, or on the contrary, to behave as a free rider (no control effort) or as a partial free rider (partial effort). In Section 5, we use a completely different representation of disease control efficiency and observe that we obtain the same qualitative results. In Section 6 (the conclusion), we highlight the risks posed by the new regulation.

2. The model: The three levels of utility

We use a deterministic model here, even though the spread of a disease is a random process. This representation is sufficient for our purposes. It should also be noted that many orchards susceptible to plum pox are located on farms with other activities not exposed to this risk (other species of fruit trees, other activities than arboriculture).

2.1. Utility of each tree grower

The production utility of the orchards at risk for each producer can be expressed in a very simple way as the fruit production multiplied by the unit price, minus the production costs.

$$u(i) = p(i).m(i) - costs(i)$$

where $p(i)$ is the price (excluding all taxes proportional to production) in €/tonne of fruit sold by the tree grower i, $m(i)$ is the mass of fruit produced by the grower i, expressed in tonnes, and $costs(i)$ is the amount of costs associated with this production (structural costs, material costs, intangible costs such as contracting, costs associated with the knowledge required for the activity, and certain taxes; expressed in euros).

2.2. Collective utility of the tree growers

The collective utility of tree growers is called u(A). It can be defined as the sum of the utilities of each producer for the year under consideration.

$$\mathrm{u(A)} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{u(i)}$$

Note that the contributions of each tree grower to the collective utility are not differentiated; this could have been done differently by using a weighted sum, if such weighting were justified.

2.3. Utility of the State

The utility of the State resulting from arboriculture is considered to be the utility of the tree growers and the utility of other members of society, i.e., processors, transporters, traders, consumers, etc. In addition to this economic and social utility (the jobs created), it also includes environmental aspects (such as the value of the landscapes thus created and maintained).

3. Tree grower effort and externalities

Let's suppose that each grower i makes an effort to control plum pox, an effort represented by its cost $c_i \geq 0$, which adds up to the production cost 'costs(i)' from the previous section. Let's also suppose that the result of the combined efforts of all tree growers is a change in the utility $u(i)$ of tree grower i, a change defined by a multiplicative factor $w(\sum_i c_i)$, with $w' > 0$ and $w'' < 0$.

These properties of the variation in the multiplicative factor can be explained as follows: the greater the sum of the efforts, the greater the effect on the grower i, but this growth becomes smaller and smaller as the sum of the efforts increases.

The optimal effort of each grower is then obtained as the solution of:

$$\max_{c_i} w\left(\sum_i c_i\right).u_i - c_i \qquad (1)$$

If the control actions are performed independently by the growers, the necessary optimality conditions lead to a solution in terms of optimal cost c_i^0 for grower i, solution of Equation (2):

$$\begin{cases} w'\left(\sum_{j\neq i} c_j + c_i^0\right).u_i - 1 = 0 \text{ if } c_i^0 > 0 \\ w'\left(\sum_{j\neq i} c_j\right).u_i - 1 < 0 \text{ if } c_i^0 = 0 \end{cases} \quad (2)$$

The first case corresponds to an 'internal' solution, where tree grower i contributes a non-zero (but not necessarily very important) share to the collective effort. The second case (second line) is one in which the effort of the others is such that any additional effort made by tree grower i results in an additional cost that is not offset by the increase in his own utility; in this case, it is in his interest not to make any effort (to detect or eradicate the affected trees).

This simple representation already reveals a possible free rider behaviour (in the sense given to it by game theory: the free rider benefits from the transport by a boat financed by passengers other than himself or herself), where an economic agent benefits from the effort of others without contributing to it himself (hereafter referred to as 'pure free rider'). Or he contributes to some extent, but the bulk of the effort is borne by others[25,26]. This is all the more plausible as it is not easy to verify the effort that each individual makes to fight the disease[27]. We will return to this problem of free riding in Section 4.

For the moment, however, let us consider a particular group of tree growers, for example those who grow only certain fruits (e.g., apricots), or those who grow in a particular small region, or those who have a particular type of contract with companies, or a particular quality label... Let us denote this group I and suppose that it carries out coordinated actions with a global cost $\sum_{i\in I} \hat{c}_i$. Then the optimal effort of this group will be such that it optimises its own utility and, following the previous reasoning, it will satisfy the following necessary conditions of optimality:

$$\begin{cases} w'\left(\sum_{j\notin I} \hat{c}_j + \sum_{i\in I} \hat{c}_i\right).\sum_{i\in I} u_i - 1 = 0 \text{ if } \sum_{i\in I} \hat{c}_i > 0 \\ w'\left(\sum_{j\notin I} \hat{c}_j\right).\sum_{i\in I} u_i - 1 < 0 \text{ if } \sum_{i\in I} \hat{c}_i = 0 \end{cases} \quad (3)$$

This group may thus itself behave as a free rider; this is indeed the case for many so-called alternative production systems that benefit from disease control in neighbouring 'standard' crops.

In the case where the effort of the members of the group under consideration is not zero (i.e., they are not pure free riders), which corresponds to the first equation of (3), we find that:

$$w'\left(\sum_{j\neq i} c_j + c_i^0\right) = \frac{1}{u_i} > \frac{1}{\sum_{i\in I} u_i} = w'\left(\sum_{j\notin I} \hat{c}_j + \sum_{i\in I} \hat{c}_i\right) \quad (4)$$

However, we have seen that $w'' < 0$. We deduce from Equation (4) that

$$\sum_{j\neq i} c_j + c_i^0 < \sum_{j\notin I} \hat{c}_j + \sum_{i\in I} \hat{c}_i \quad (5)$$

Each term in inequality (5) represents the sum of the efforts made by all tree growers. This means that the efforts induced by the existence of group I are more important than the efforts made when this group does not exist. And they will be all the more important the greater the difference between the two terms in the previous inequality, i.e. all the more important the sum of utilities in the group I is.

It follows that if we want to obtain the value of the maximum net variation in utility that can be achieved by all tree growers, we need to set up the largest possible group. In other words, all growers should be involved in this group effort, whose rules of pathology control should apply to all. Thus, by decentralising the detection and control of plum pox, the new European directive described in the introduction is in danger of destroying value and utility, as control becomes more individual and less collective.

The maximum utility that can be achieved, taking into account the cost of controlling the disease, is then given by

$$\max_{\hat{c}_i}\left(w\left(\sum_i \hat{c}_i\right)\right).\left(\sum_i u_i\right)-\sum_i \hat{c}_i \tag{6}$$

This total utility resulting from the coordinated action of the tree growers is greater than the total utility that can be achieved if the actions are not coordinated. It is possible to calculate the difference between them, called Δ; it is written:

$$\Delta=\left[w\left(\sum_i \hat{c}_i^N\right)-w\left(\sum_i c_i^0\right)\right].\left(\sum_i u_i\right)-\left(\sum_i \hat{c}_i^N-\sum_i c_i^0\right) \tag{7}$$

with the exponent *N* for costs when actions are coordinated and 0 when they are not.

In the context of our hypotheses, Δ is the quantification of the potential loss induced by the new directive at the level of tree growers only, i.e., without taking into account the social, environmental and other indirect economic effects.

4. Free-rider behaviour

One may wonder whether or not a tree grower has an interest in joining a group of other tree growers beyond any regulatory obligation.

As before, Δ is the surplus of utility, expressed in monetary units, due to the coordinated actions within this group. Suppose that tree grower *i* receives a share of it, denoted Δ_i, for example in the form of a monetary payment from the group. In total, for all the surplus to be redistributed, we have $\Delta=\sum_i \Delta_i$. We can represent the problem of tree grower *i* as being to determine his optimal level of effort by solving the equation:

$$\max_{c_i} w\left(\sum_{j\neq i} c_j + c_i\right).(u_i+\Delta_i)-c_i \tag{8}$$

In order for the group to obtain the surplus utility Δ thanks to the efforts of the various tree growers affiliated to it, each Δ_i must be calculated so that the solution of (8) for each *i* involves efforts c_i such that the surplus utility Δ is effectively obtained. Since this calculation of Δ_i is quite complicated, it is simply not possible to implement such individualised redistribution in practice.

On a general level, whether or not such a group is created, going back to Equation (1), each tree grower may be tempted to become a 'free rider'. This will be the case in particular if for a grower the optimal solution to Equation (1) is $c_i^0=0$, i.e., if

$$u_i < \frac{1}{w'\left(\sum_{j\neq i} c_j\right)} \tag{9}$$

In other words, all tree growers whose utility is below a certain value will have a zero level of effort, and only those tree growers for whom the stakes are sufficiently high will make an effort to control the disease.

Two comments: firstly, all those with small areas (including recreational or hobby tree growers), or all those who make little profit from their work (if the selling price of the fruit is too low compared to production costs), will be in the first group. We have not included any inter-temporal considerations here, simply to avoid complicating the equations, but it is clear that tree growers who plan to stop production in a few years' time will fall too into this group.

The second comment concerns those in the second group who will make an effort to combat the disease. On the one hand, we have seen that the smaller the utility of the group of growers, the smaller the effort. The more free riders there are, the smaller the number of those fighting the disease and the smaller the effort made by each of them, leading to a dynamic of effort that may stabilise at a necessarily lower level of production, or even at zero.

5. Another representation of control interest

Plum pox (or sharka) is a specific pathology (aphid-transmitted virus), whose dynamics are well described in several articles[9,28–30]. The overall effectiveness of the control may not be a function of the sum of the efforts, represented by $\sum_i c_i$, but of the minimum effort, $Min_i c_i$. It is then sufficient for a single grower to make no effort, either in detection or in control, for the increase in utility, relative to a situation without any detection or control, to be zero for all. Each tree grower then solves:

$$\underset{c_i}{\mathrm{Max}}\left(\mathrm{w}\left(\left(\mathrm{Min_j c_j}\right).\mathrm{u_i}\right)-\mathrm{c_i}\right) \tag{10}$$

whose solution is:

$$\begin{cases} \mathrm{w}'(\mathrm{c_i}).\mathrm{u_i}-1=0 \text{ that is } \mathrm{w}'(\mathrm{c_i}) = \dfrac{1}{\mathrm{u_i}}, \quad \text{if } \mathrm{c_i} > 0 \text{ and with } \forall \mathrm{j} \neq \mathrm{i}, \mathrm{c_j} \geq \mathrm{c_i}, \\ \mathrm{c_i} = 0 \text{ otherwise, wathever the value of } \mathrm{w}'(0).\mathrm{u_i}-1 \end{cases} \tag{11}$$

The optimal effort for each of the growers *i* will be non-zero, i.e., they will all have an interest in detecting plum pox and controlling the disease, if there is a non-zero solution to Equation (11). This corresponds to the situation in the first row, which requires that:

$$\forall \mathrm{i}, \exists \mathrm{c_i} > 0 \;/\; \mathrm{w}'(\mathrm{c_i}).\mathrm{u_i}-1 > 0, \tag{12}$$

i.e.:

$$\forall \mathrm{i}, \exists \mathrm{c_i} > 0 \;/\; \mathrm{u_i} > \frac{1}{\mathrm{w}'(\mathrm{c_i})} \tag{13}$$

Again, this is not guaranteed if some tree growers have utilities that are too low in relation to the cost of the individual effort, for all the reasons given above.

If now a group *I* of tree growers is set up, which imposes a minimum effort c^I on each of its members, the equation becomes:

$$\begin{cases} \mathrm{Max}_{\mathrm{c_i}} \mathrm{w}(\mathrm{Min_j}(\mathrm{c_j})).\mathrm{u_i}-\mathrm{e_i} \\ \text{with the constraint: } \mathrm{c_i} > \mathrm{c^I}, \forall \mathrm{i} \in \mathrm{I} \end{cases} \tag{14}$$

whose solution is $\widehat{c_\iota}$. In this case, the solution of the optimal control cost calculation problem for tree grower *i* will be non-zero if, even outside this grouping, all tree growers also make sufficient effort, i.e., if

$$\forall \mathrm{j} \notin \mathrm{I}, \exists \mathrm{c_j} > 0 \;/\; \mathrm{u_j} > \frac{1}{\mathrm{w}'(\mathrm{c_j})} \tag{15}$$

In other words, as in the previous representation, in order for the effort to be non-zero, this group will have an interest in including among its members all those tree growers (in this case those with the lowest utility) who would otherwise not make this minimum effort.

Since for the other growers, this level of control costs is already reached or exceeded, the group has an interest, for simplicity's sake, either in including among its members all the growers who would not make this minimum control effort, or in ensuring that this minimum effort constraint is imposed on each of the growers without distinction (of utility, of area, of membership or not of this group). Each tree grower of this group therefore has an interest in contributing to the implementation of a lobbying system to impose a minimum effort on all tree growers (effort which is the solution of (14), with $c^I = \widehat{c}_i$).

6. Conclusion

As we have seen in the two models in Sections 4 and 5, whether the effectiveness of the measures depends on the sum of the efforts or on the minimum effort, it is important to form a group that is as large as possible, i.e., one that includes all the tree growers. And to avoid free-riding or very complicated calculations, it is also necessary to impose common effort rules. This is the raison d'être and the role of the French OVS (French acronym for Health Organisation: Organisme à Vocation Sanitaire). However, as we have seen, these rules will not have the same interest or the same cost for each tree grower, which can be a source of conflict within the OVS[21].

In practice, it is important that all tree growers cooperate in the detection and removal of affected trees or plots. This was the case under the previous regulations, which classified plum pox as a 'quarantine pest', making detection and control compulsory and, above all, compensating tree growers for their losses. Even if this compensation was not total (it was a flat rate per tree or per hectare), and did not take into account the imbalance in production costs at farm level, losses on the market, etc., as this would have posed great difficulties of evaluation, the growers felt, and indeed were, supported by the public authorities in their detection and control efforts. Implicit coordination ensured that similar efforts were made by other tree growers who did not benefit from the sacrifices of one without giving anything in return.

The reshuffling of the cards, the downgrading of plum pox from one of the most serious diseases (against which control is compulsory and financed by all actors, including the State) to a disease whose control must be organised mainly by producers alone, with the possible withdrawal of the State, does not guarantee that we will not find ourselves in the situation of certain countries where almost all trees have been affected[7].

Such a resurgence of the disease would then be fatal for the affected orchards, and possibly for the affected tree growers, with a whole cascade of negative economic, social and environmental consequences.

What is also very important is that these results can easily be generalised to any problem of conservation of natural resources whose management is delegated to private stakeholders.

So, the conservation of natural resources, when their management is delegated to private partners, must take account of global change (economic, climatic, epidemiological, etc.); but this conservation is also very dependent on the regulatory context in which it takes place. It also depends on possible and more or less anticipated evolutions of this context when the resources are not renewable (non-renewable resources), or when their renewal requires a significant amount of time (which is the case for forests, and more generally for all trees).

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Conflict of interest

The author declares no conflict of interest.

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