

MAKING VIRUSES MORE SOCIALLY ACCEPTABLE: A SOCIOLOGICAL FRAMEWORK FOR VIRUS-BASED PLANT PROTECTION PRODUCTS

Abstract. *A new class of biopesticides in agriculture is being developed in Europe. This biotechnological innovation is based on the use of a virus as a biocontrol agent and is presented by scientists in response to the EU policy of reducing chemical pesticides; yet, the negative social image of viruses could act as a brake on innovation and worsen the fiduciary pact existing between technoscience and society. This contribution aims to trace the theoretical space for social acceptability within risk analysis, first by looking at how the scientific image of viruses has changed and, second, by proposing a sociological framework for investigating the social image of virus-based biotechnological innovations.*

Keywords: *social acceptability, risk analysis, virus, biotechnology, agriculture; VIROPLANT; biopesticides*

Introduction

Recent changes are affecting the European policy of regulating pesticides in agriculture, limiting and restricting their use due to their toxic effect on human and animal health and their unsustainable impact on the environment. Producers and policymakers have for decades been engaged in an arm wrestle, fighting for economic interests and exerting technoscientific knowledge as a flexible weapon capable of reducing their counterparts' influence. This conflictual view, nevertheless, affects the ways in which risk and innovation are shaped in the public sphere, generating growing confusion and cognitive dissonance. While elaborating sustainable alternatives in the area of plant protection, many researchers are moving their attention to the ecological role of microorganisms (i.e. bacteria and viruses) in terms of *biocontrol* and experimentation for future exploitation in agricultural practices. Although many positive results have emerged in the last 20 years, viruses are still linked to a negative social image, as pathogens against life,

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** This work was supported by the European Union's Horizon 2020 Research and Innovation Programme (773567; accessible at www.viropiant.eu).

which reveals the crucial *knowledge gap* typical in biotechnology between scientists, experts, stakeholders and laypeople. During a time of ecological crisis, a theoretical understanding of this gap helps to rethink risk analysis as a communication process by which actors and institutions exchange a complex set of resources to cope with uncertainty and to establish a new definition of the situation.

This contribution aims to give an initial insight into the scientific and socio-epistemic context of an emerging virus-based biotechnological innovation (BTI) in the plant protection promoted by the VIROPLANT H2020 project (2018–2021). An introductory paragraph on pesticides describes some preliminary elements on the margins of this BTI, but crucial to social acceptance. An *excursus* concerning the shift in the definition of a virus will underscore the importance of research into the social acceptance and acceptability of the VIROPLANT project relative to similar cases of controversial innovations. Finally, a sociological model for risk analysis is presented as a theoretical tool which guides our sociological empirical work within VIROPLANT.

The regulation and research agenda of plant protection

In modern societies, the impact of technological development on the environment has led to the stronger and closed interdependence of several agents with different levels of expertise, experience, power and commitments, which requires coordination, delegation and means to monitor effectiveness and efficiency (Pellizzoni, 2011). This kind of relational complexity expresses the quality of our socio-economic system insofar as the *industrialisation of agriculture* is perceived as an irreversible process of the protection of production and quasi-isolation of agroecosystem from pathogens and other threats, like pollution and soil depletion, to meet the market's demand for productivity which, in turn, depends on social value and political planning. According to Lucien Demonio, agrarian production depends so closely on the hazards of the cycle that it is never possible to estimate in advance the quantities produced, nor to determine the exact timing of the main operations. The watch's *isomorphic time*, on which the precision and execution of industrial work rests, is opposed to events' *discontinuous time* of agricultural labour; in this perspective, it is in the immediacy of the relation between the action of the natural factors and the course of the process of production that practical control of the cycle is achieved (Demonio, 1979: 225–226). Moreover, it is remarkable that one of the elements of chemical pest control is its *structural coarseness*, modelled on the behaviour and risk culture of operators who, using what is available in the market, aim to simply suppress the vulnerable agent of the crops (Beato, 1992: 117). It is a sort of

preventive suppression in the sense that the chemical antiparasitic treatment is put in place before the appearance of the phytophagous insect (which often may not even transpire). In routinising these methods, it is easy to exceed the necessary threshold established by the scientific control rules, especially in dramatic cases of geographical competition between farmers and markets. From the point of view of a naïve environmentalism, the industrialisation of agriculture contains a paradox whereby: the efforts to make production less vulnerable to external vulnerable agents worsen the condition of the ecosystem, and the possibilities for intervention and experimentation. A vicious circle emerges, nourished by the will of the dominion and exploitation of natural resources, at the expense of traditional assets and spontaneous regeneration and lifecycle, which may suggest or impose a claim to return to a previous state of complexity. Another complementary paradox then appears: abstinence of technoscientific devices increases the agroecosystem's vulnerability and by regaining traditional low-tech devices and practices agrarian production is exposed to greater vulnerability. As Fulvio Beato asserts, "it would be interesting to work around a historical sociology of agriculture that confronts [agrarian work] with its huge defence system from a vulnerant external environment" (Beato, 1992: 116). Indeed, a historical sociological look offers a way out from the double political impasse of *technophobia* and *technophrenia* (Cerroni, 2007) by providing tools and models of interpretation, and event reconstruction at a higher level of complexity; moreover, now that citizen engagement has become one of the trending topics of the EU's research programme.

Pesticides seem to be at the core of the agroecosystem policy agenda, but their history shows an unclear consensus. In the early 1970s, Headly and Lewis described a difficult situation in risk communication

marked by a certain amount of defensiveness on the part of conservationists, agriculturalists, scientists, and the chemical industry. Consequently, the layman has been exposed to many statements through the various media – a good percentage of which have been launched from a defended position. The difficulty in obtaining a calm and dispassionate account of the situation has made the job of policy making more difficult. (Headley and Lewis, 1970: xiv)

Recently, Bozzini (2017) conducted important introductory research on the interstitial space of *pesticide policy* in the European Union that provides and sets the historical context, while analysing in depth the principles and procedures of the EU's pesticide regulation. She initially clarifies how the key concept of pesticide is used not only on the regulatory level, but also in the public sphere. In a first approximation, pesticides refer

to a variety of substances and products that according to their function can be grouped into herbicides, insecticides, fungicides/bactericides and molluscicides (meant to fight against snails). All together, they are also called phytopharmaceuticals or – with a gentler term used in European Union (EU) regulation – “plant protection products” (PPPs). (Bozzini, 2017: 1)

Within this conceptualisation, one finds a wide range of substances, from synthetic chemicals as well as naturally-occurring toxic substances and microorganisms. According to MacBean (2012), around 1,500 active substances are variously commercialised in tens of thousands of products, and tested for their effectiveness for fighting pests. From the regulatory point of view of FAO, the definition of pesticide is broader and includes “any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth” (FAO, 2014: 6). By including a plurality of entities, *pesticide management* is

the regulatory and technical control of all aspects of the pesticide life cycle, including production (manufacture and formulation), authorization, import, distribution, sale, supply, transport, storage, handling, application and disposal of pesticides and their containers to ensure safety and efficacy and to minimize adverse health and environmental effects and human and animal exposure. (FAO, 2014: 6)

While it may be beyond doubt that PPPs play an essential role in protecting agricultural production and guaranteeing stable food supplies, Bozzini argued

at the same time, pesticides are nonetheless chemicals deliberately released into the environment to kill living organisms and for this very reason can have adverse effects on human and animal health, and natural resources. This tension between the need to deliver food security and guarantee food safety lies at the heart of policy and politics on PPPs in every regulatory regime. (Bozzini, 2017: 2)

In this scenario, with the admixture of interests from the agroindustry system and environmentalist non-governmental organisations, the official position taken by EU institutions lies in between, pushing for a policy goal of an overall reduction of the use of agrochemicals in plant protection, and promoting strategies for the protection of plant products and food supplies. Indeed, increasing resistance to old chemical products is conceivable

as a pushing faction in innovation, forcing a change of mind among both agricultural operators and regulatory agencies. In this sense, we can see an emerging movement of a convergence from a chemical control strategy towards so-called *biopesticides*, which represents

in terms of environmental impacts, the most promising innovation [...]. These are made from natural materials – like pheromones – and living organisms – like bacteria, fungi, viruses – which are used to control pests via natural mechanisms like predation, parasitism and chemical relations. Research on biopesticides is a fast-growing area of development, and more than 80 new biological active substances have been approved in the EU and more than 200 in the USA. (Bozzini, 2017: 6)

Confronting old and new generations of PPPs, there is evidence that biopesticides, on which several research projects in the EU context are based, bring a lower risk to consumer health. An innovation relying on biocontrol strategies and their lower environmental impact nevertheless needs a radical reorganisation of the interdependence between the agricultural sector and technoscientific research, and the stringent control of meddling stakeholders. Indeed, every technoscientific innovation is at once the cause and effect of a socio-cultural innovation; in this case, it implies a conversion from the traditional *biological struggle* based on the antagonism between organisms to new images that would incorporate the use of organisms' products, the adoption of genetic methods and the use of other means following ecological principles that could promote the "convinced cooperation of research organizations and political-administrative bodies, on the one hand, and of economic structures on the other" (Beato, 1992: 125).

Beyond this optimistic vision that is confirmed by a new approach known as "European Innovation Partnership" in agricultural sustainability and productivity (Lamichhane et al., 2016), over the last 20 years the transition towards a regime with less pesticide use has still been problematic. The main criticism concerns assessment methods at both the national and EU level. In her evaluation of EU regulatory action for the period 2000–2010, Bozzini reports three main indicators. For the first point, great variation in the use of PPPs emerged "depending on economic development, farming methods, climate, as well as more contingent factors like exceptional pest attack. It also depends on the type of cultivation" (Bozzini, 2017: 110–111). As the use of pesticides in Europe is not decreasing, the standardisation of monitoring programmes remains critical and unsystematic: regarding the second point, a report on the Water Framework Directive (European Commission) published in 2015 highlights that "gaps in monitoring the chemical status of surface waters were so significant that in 2012 the status

of over 40% of water bodies was unknown and it was impossible to establish a baseline” (Bozzini, 2017: 110). As a third indicator, data on pesticide residues, the latest EFSA annual report reveals quite a positive situation, concluding that “according to the current scientific knowledge, the long-term dietary exposure to pesticides covered by the 2016 EUCP was unlikely to pose a health risk to consumers” (European Food Safety Authority, 2018: 95). The space for the diffusion and experimentation of biopesticides encounters a setting characterised by the resistance of local operators, difficulties in communicating with regulatory authorities (i.e. the EFSA), a lack of data on environmental conditions, as well as incomplete implementation of the new integrating platform for PPP policy, even in a geopolitical perspective (Rodgers, 1993).

Apart from these factors of resistance, the social acceptance of biopesticides encounters another set of difficulties at the level of knowledge, about a social imaginary related to virus. Before considering that analytical level, it is worthwhile briefly focusing on why viruses can be so useful in agriculture.

What is a virus?

In her review work, Roossinck (2011, 2012) describes a shift in the definition of a virus that occurred in the last 20 years, showing how the state of knowledge at a given time reflects the physical state of research-making and the theoretical framework or paradigm. As we know from the sociology of knowledge, distinctions between the possible and impossible and the probable and improbable (Esposito, 2008) lie at the core of techno-scientific innovation; indeed, what we know about viruses depends on the technologies of detection, which are based on an epistemological model and socio-historically determined materials (Colella et al., 2019). From these sociological assertions about the nature of the techno-scientific system, and the circular character of abstract meanings and concrete artefacts, the redefinition of virus implies a reconfiguration of the vocabulary of the plurality of the interconnected fields, such as virology, phytopathology and immunology, but also policymaking and media communication.

Regarding the history of virus, in his influential book *Viruses and Man* Frank Macfarlane Burnet (1899–1985) defined a virus as “a microorganism responsible for disease which is capable of growth only within the living cells of a susceptible host and which is normally considerably smaller than any bacterium” (Pradeu, 2016: 81). Another definition was proposed in 1997 by a group of virologists gathered in a workshop held in Santa Rosa National Park, Liberia, Costa Rica to discuss the possibility of creating an inventory of virus biodiversity. On that occasion, viruses were defined as:

“intracellular parasites with nucleic acid capable of directing their own replication, that do not serve any essential function for their host, have an extrachromosomal phase and are not cells” (Roossinck, 2011: 99). These two definitions are incomplete since they exclude several phenomena like endogenised retroviruses and integrated proviruses of bacteria, and a class of so-called beneficial viruses. In general, from the outset until recently, viruses were viewed as pathogenic according to the etymology of the term (*vira* in Latin means “poison”, although its Indo-European root *vis is a little different, expressing the quality of being *active*, *operative* and even *aggressive*). For many reasons, this stringent definition (or reduction) of virus to something harmful and dangerous was useful in detecting disease-causes and elaborating medical strategies and therapies; but its strength was also its weakness. A psycho-sociological effect of an *institutionalised confirmation bias* is found in Nobel Prizes awarded to the virology field which were explicitly presented as the discovery of disease-causing viruses, such as HIV and human papilloma virus in 2008 (Weiss, 2008). Along with pathogenicity, viruses can be harmful in other ways, such as reducing host fertility or manipulating host behaviour; hence, “it seems more accurate, therefore, to say that viruses have generally been seen as fitness-reducing entities, most of the time through their pathogenic effects” (Pradeu, 2016: 81). The strength of a pathogenic frame of reference, based on an interpretation of the immune system as a defence system at war with pathogens, has influenced the direction of scientific inquiry and research funding as well as the social recognition and awareness of the role of viruses in everyday life. In terms of the sociology of knowledge, we can detect here a mutual reinforcing relationship between epistemological and policing definitions of virus: if a disease is defined as a threat to a defence system, then its cause is thought and treated as an absolute enemy. Therefore, re-framing the role of viruses will trigger a re-thinking of how our immune system works.

In her works, Roossinck has reviewed a set of phenomena incompatible with the pathogenicity framework as cases of “symbiosis mutualism”, the special behaviour of two or more entities which increase host fitness in several ways. Symbiosis in nature is a common situation at both the macro and micro level when two distinct entities live in an intimate association. There are at least three types of symbiosis, depending on the specific quality relationship and exchange between the parts: a) antagonism, when one partner benefits at the expense of the other; b) commensalism, in which one partner benefits and the other is unaffected; and c) mutualism, when the relationship between the partners not only benefits them but also increases their fitness (i.e. their reproduction capacity) (Roossinck, 2011: 99–100). Regarding this last case, it is possible to look at the impact of mutualism on host development, protection, and on invasion capacity. Recent studies on beneficial

effects of a virus on the host's development have correlated the evolution of placental mammals with an endogenous retrovirus (Pradeu, 2016: 82–84).

Endogenisation, as result of immunisation to an otherwise lethal virus, is not only a vital event for the individual but also for evolution of the species. Symbiotic mutualism is a sort of fusion of two symbiotic entities that becomes essential for the host's survival and for virus specialisation, attenuating damage caused by other viruses or pathogens. In their capacity to kill competitors, viruses help their hosts adapt to environmental threats and changes (Roossinck, 2011: 100); a deep understanding of the functioning of what biologists call the "virobiota" (the community of viruses within a host) and the "virome" (the set of all gens of the virobiota), allows a new hypothesis about the role of mutualistic bacteria living in the host that could be due to the presence of mutualistic viruses (Pradeu, 2016: 82–83), like in the case of the human gut microbiome where "undoubtedly we will find that many of the beneficial effects of the microbiome are encoded by viruses" (Roossinck, 2011: 106). A recent study in the field of human virobiota considered persons in close contact with each other, who – it has been shown – share a fraction of their oral virobiota, a potentially negative implication for the efficacy of antibiotics (Abeles and Pride, 2014). The shift from a pathogenicity-oriented definition of virus to a new one that highlights a virus' role in the mutualistic relationship, and generally for the ecological fitness of the host in its environment, holds several theoretical and practical consequences: a change in the way of searching for new viruses; a re-conception of the interaction between the host immune system and other microorganisms; the development of A new therapeutic virus-based approach (virotherapy); and a re-evaluation of the idea of the autonomy of living things (organisms and micro-organisms) (Pradeu, 2016: 84–86). Regarding virotherapy, the most popular example is "phage therapy", which is still considered too dangerous in many Western countries; another kind of experimentation for treating cervical cancer involves genetically-modified viruses that might strengthen the patient's immune system (Crawford, 2002: 193–194). Some plants have been genetically modified to express viral proteins, while transgenic bananas already exist that produce the surface proteins of the *Hepatitis B* virus and potatoes that produce proteins of *rotavirus*; the idea of an "edible vaccine" seems to be a good solution, acting directly on the natural site of the infection for viruses such as *rotavirus* that affect the intestine (Crawford, 2002: 222). There are also other historical examples of strategic uses of viruses as "natural weapons". In the 1950s, there was the first and most famous case of using a virus as a biological control agent when the *myxomatosis* virus was spread in Australia and the United Kingdom to control the proliferation of wild rabbits (Bartrip, 2008); a strategy of intervention that also occurs in micro-organisms like bacteria and yeasts that "have

evolved systems to beat their competitors by killing them with the aid of viruses (Roossinck, 2011: 103). In conclusion, the existence of mutualistic viruses has been known for some time, but the claim based on the current data is different and much stronger than previous ones, and suggests “a more general reconceptualization of viruses, at the interface between medical and ecological-evolutionary approaches” (Pradeu, 2016: 80).

Some potential critical aspects of the social acceptance of virus-based PPPs

The history of pesticides has shown a gradual rise in their social unacceptability due to both relational and ecological factors. However, the regulation of plant protection drafted with the characteristics of pesticides in mind influences actual innovation in biocontrol products, causing delays in their application and commercialisation. Designing a brand-new regulation for virus-based PPPs requires a certain amount of experimental data and also a change in the social perception of viruses. VIROPLANT (acronym for Virome NGS Analysis of Pests and Pathogens for Plant Protection) is a H2020 RIA project related to the “Innovation in plant protection” work programme (SFS-17-2017) whose main goals are to explore the ecological role of viruses in plant protection, propose biocontrol strategies as an alternative to the use of pesticides, and provide new tools for use in integrated disease and integrated pest management for conventional, integrated and organic farming. Seventeen participants (research institutes, universities and associations) from eight EU countries are members of the consortium. Applying next-generation sequencing (NGS) techniques to identify new viruses, VIROPLANT will also rely on the Virus Induced Gene Silencing (VIGS) approach to target fungal disease, pests, and pest-transmitted diseases. The project contains two work packages for the social sciences: WP5 on “Techno-economic system analysis, business models, theoretical risk assessment for regulatory issues” and WP6 on “Social and gender-specific acceptance of virus-based natural and engineered products”. Working on WP6 (led by the MaCSIS Centre of the University of Milan-Bicocca), our objectives are: a) to map the collective imagination concerning viruses in terms of public perception, and hazards and risk, which orients production and consumer behaviour; and b) to provide an indication for communication strategies in order to identify the drivers and cope with the resistances. According to the EU’s interest in the anticipation of the socio-economic consequences of innovation, the benefits considered by the consortium are not solely limited to the sphere of making progress in knowing and improving biotechnological products so as to bring about a reduction of pesticides, but also involve addressing the regulatory issues required for registration

of natural viruses for biocontrol within the EU to develop environmentally safe and friendly products, while preventing distrust and indirect obstacles arising from public opinion. This anticipatory aspect will be crucial for supporting and funding new (unknown) innovations in the area of plant protection according to a systemic conception of the precautionary principle (Troncarelli, 2007). For all these reasons, exploring social acceptability is not strictly required to implement an appropriate communication strategy concerning VIROPLANT's purpose and outcome, but it covers a wide range of aspects from a redefinition of agricultural practices to a reconfiguration of the ecological role played by microbiotas and virobiota in everyday life. In a review of the literature conducted in the project's first year (Deliverable 6.1. to be published in November 2019), we found a lack of specific literature on the sociological dynamics of the acceptance and perception of PPPs and a recurrent connection with human health issues, from phage therapy to vaccines. Phage therapy is the most popular example of using a virus in human healing, and its social acceptance is worked on at a regulatory and institutional level: it is not, so far, a matter of open public discussion but an argument in the doctor-patient relationship. As mentioned, there has historically been a shift in the way virus is defined: from a negative and military conception (virus as an enemy of health and life) to a more complex one, which considers the relevance of the ecological role of viruses in different relations and environments. In relation to phage therapy, there is a tendency to frame viruses in terms of *medicalisation*: to cure pathology with virus-based medicine. In communicational terms, this frame acts by way of 'counter-storytelling' in the public sphere against the taken-for-granted knowledge that viruses are 'always bad'. In this way, a virus counts as a lethal weapon to be used in extreme cases, as *extrema ratio*. From a sociological view, this frame of reference promoted in phage therapy fosters and stimulates a conflictive schismogenesis between scientists and citizens. Second, acceptance without awareness produces new risky forms of *negative knowledge* (see below), as in the case of the antivax movement. At first blush, these two effects may be seen as a positive starting point for developing a communicative strategy for social acceptance due to the *confinement* within an expert zone with a top-down relational logic with social actors. In other words, social acceptance is meant as a threshold between passive acceptance and active unacceptance, intended as a problem to cope with. In deeper analysis, it is possible to explore the 'dark side' of experts (what they do in order to obtain social acceptance) in terms of biases which influence not only the science and society relationship but also science and markets, and the general image of scientific roles and professions. An example related to virus exploitation in medicine is a strategy of trickery to use a misleading name of commercialised product or, in the case of phage therapy, to avoid using the term "virus"

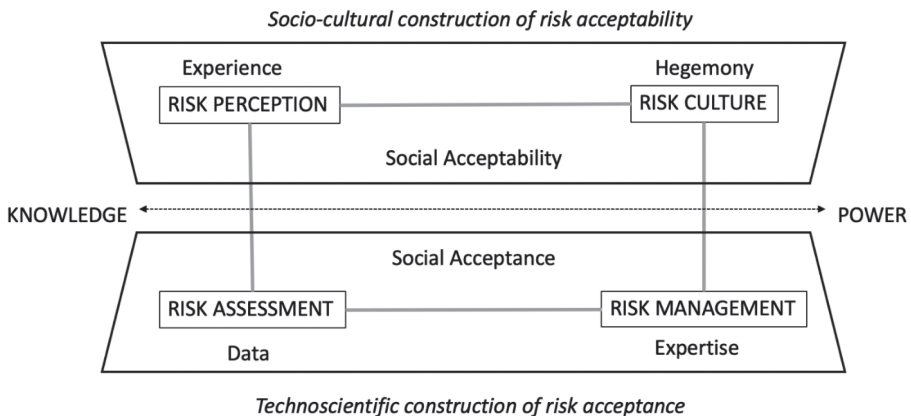
to describe them. On the side of laypeople, social acceptance is based on a delegation and fiduciary principle and may generate unawareness in terms of both trust and indifference; a condition which is a natural effect of social differentiation. Still, it could produce a passive attitude to complex arguments holding high civic relevance, like atomic energy. As we found in Apulia's *Xylella fastidiosa* case (Colella et al., 2019), in controversies over expertise a rapid shift from unawareness to critical thinking is typical which, in absence of a dialogue with institutions, mediators and scientists, takes the form of conspiracy thinking. The stake of vaccines seems to be the same: a sense of *caring* about something (or feeling of losing something relevant): scientific truth or freedom of choice. Reducing mothers' movement in terms of fear or panic about their children's health is a simplification because the recent opposition has come after decades of a high level of social acceptance: every change in perception needs to be explained.

From social acceptance to social acceptability: sketching a model of risk analysis for the VIROPLANT project

Many scholars have paid attention to controversial topics raised by environmental policies and the role of lay-experts and social movements in negotiation (Frickel et al., 2010; Hess, 2010, 2016; Hess et al., 2008). From the late 1990s to the first decade of the 2000s, BTIs were at the centre of plural social actions which determined the strong opposition to the experimentation and exploitation of new discoveries in the life sciences. The success of transdisciplinary fields like bioethics may be seen as a positive effect of the public concern with GMOs; nevertheless, it caused a deceleration of the carriers in biotechnology and stigmatised biotechnological products on the public agenda, with a consequent lag in discussion and democratic participation in this subfield of scientific innovation. Risk communication becomes socially relevant when a conflict emerges in what Sandman (Sandman, 1987/2012) called the distinction between *hazard* (the entity of expected damage) and *outrage* (the meaning of damage in public perception). Voluntariness, control, fairness, morality, familiarity, memorability, dread and diffusion are the main outrage factors which, by characterising public risk perception, must be inserted in risk assessment and risk management in order to control *social amplification* (Kasperson et al., 1988). Memory of past experience and trust in technoscientists play a crucial role in the decision-making: in the case of solid institutional trust, a social group can accelerate a change without pondering on its value and alternatives; nevertheless, blind trust in experts is unable to prudently prevent a catastrophic effect due to information overload and cognitive dissonance, as happened in the case of the L'Aquila earthquake in 2009 (Benassia and De Marchi, 2017).

In an attempt to offer a spatial representation (Figure 1), acceptance can be located in the centre of the risk analysis field and conceptualised as the ultimate end of converging risk-assessment and risk-management work. A specific place for *risk production* (Cannavò, 2003; Beato, 1993) defines a socio-cultural sub-field of experience condensed in models of legitimate action based on the hegemony in charge. In the production of risk, we encounter both the reproduction and amnesia of hazard and outrage, of know-hows and standards of decision. Indeed, risk production may be considered part of a general risk culture as a socio-political organisation based on the current hegemony, relatively independent of the subjects' experience (risk perception), the re-organisation of collective action and intervention (risk management) and the measurement and standardisation of experiences, action patterns and cultural values in quantifiable data (risk assessment). The model, in this actual raw version, also represents two *continua* of tensions: between knowledge and power, or epistemology and politics (Böschen, 2009; 2013; Böschen et al., 2010); and between society and technoscience, a relationship that can be conflictual or co-operational depending on society's mandate (Stallings and Quarantelli, 1985). As an analytical tool, once can distinguish two social meanings of acceptance insofar as we look at the priority of the societal mandate of the technoscientific system (in its risk-assessment and risk-management functions) or the desire to withdraw that mandate and to re-open the negotiation on the definition of risk in all its aspects, including the establishment of a threshold and a process for selecting experts. In order to emphasise its co-productive nature, we prefer to use the term *social acceptability* to refer to the ability and capacity of agents to participate with their knowledge and power,

Figure 1: SOCIOLOGICAL MODEL FOR RISK ANALYSIS



Source: Authors' own analyses.

their cultural and social capital, in the problem setting about an unpredicted and uncertain event. Instead, social acceptance regards social responses assessed and dichotomised in a threshold (accepted/non-accepted) from which, by following an algorithm's logic, experts and authorities can design a corresponding re-action (problem-solving). Indeed, social acceptance is a measure of the exclusion of citizens from the policy chain, and their reduction to a factor to be considered so as to maintain positions, privileges and trust in the status quo. Social acceptability is closer to "adaptive management" (Gross, 2010: 76), a kind of learning process which connects technoscientific analysis to civic participation, but with a critical difference. In other words, a perspective on risk acceptability is not oriented to absorbing dissonance and uncertainty for ensuring better fitness in the socio-political environment, but consists of the exploration of latent transdisciplinary communicational means, of a potential reset of socio-cultural identity, and of the content of technoscience's societal mandate.

Given the nature of the VIROPLANT project, it has been considered fruitful to integrate this model with the sociology of ignorance theoretical tools (Gross, 2010; Proctor and Schiebinger, 2008; Gross, 2007), especially the concept of "forbidden science" (Frickel et al., 2010), a type of undone science (Hess, 2016, 2009) marked by social blame, mobilisation (which may inhibit scientists' will to explore and produce knowledge and innovation). Introducing and focusing on the *forbidden* character implicit in innovation allows us to evaluate how the social component enters into the project design and which research opportunities make it possible or exclude it. The unknowable nature of innovation can be extended to the case of the virus-based BTI promoted and investigated by the VIROPLANT project, for the renewed framework in which viruses and virobiota are interpreted and studied. Indeed, a virus is a socio-epistemic object which relies on the critical distinction between *negative knowledge* (what a virus is not) and *nonknowledge* (what a virus might be). As many resistances are found in the actual work of operators in agroindustry about the use of pesticides, it is reasonable to speculate on the shape of the social response to this kind of BTI. According to our framework, the epistemological base from which the opposition to an innovation would come out (insights, hypothesis, scientific evidences, projects in *nonknowledge*) is secondary; in first place, in as much as the experiences and culture of people shape the value of innovation in terms of outrage, then technoscientific research (along with regulatory authorities) will be considered in the framework of *forbidden science* (and politics), and their agents would be perceived as disconnected from society as a whole. *Forbidden science* is a judgement, a label used to condemn a research-and-policymaking asset for its (perceived) disruptive and *negative knowledge*. From the perspective of scientific field, that label is an

internal boundary (endogenous or exogenous) which has impacted the actual decisions in design projects and career/funding possibilities. In this sense, society's *negative knowledge* affects scientists' *negative knowledge*; but in order to reduce the risk of the label of *forbidden science*, scientists must simultaneously consider in their work the state of society's *nonknowledge*, especially in dissemination activities.

In conclusion, as Abbott stated, "expert ignorance is among the most dangerous. For it makes us unable to see the new. Our very memory begins to prevent us from learning" (Abbott, 2010: 188). With this sociological frame which combines *knowledge*, *nonknowledge* and *negative knowledge* within a model of risk analysis, we are empirically exploring the shape of social acceptability of virus-based PPPs, highlighting controversial grey areas not only in risk communication but also in other areas of risk analysis. Indeed, a *sustainable* leap into the unknowable involves deep awareness and proper acknowledgment of what is valued as *acceptable*.

Conclusion

This contribution presented the theoretical space for social acceptability within risk analysis, first by looking at how the scientific image of virus has changed and then by proposing a sociological framework for investigating the social image of virus-based biotechnological innovations. A new class of biopesticides in agriculture is developing in Europe. This biotechnological innovation is based on the use of a virus as a biocontrol agent and is presented by scientists in response to the EU's policy of reducing chemical pesticides; yet, a negative social image of viruses could act as a brake on innovation and exacerbate the fiduciary pact between technoscience and society. One of the primary results of this contribution is that the case of virus-based BTI promoted and investigated by the VIROPLANT project could be extended to the more general problem of forbidden science. Namely, insofar as the experiences and culture of people shape the value of innovation in terms of outrage, then research and policy-making will be considered within the forbidden science frame. Forbidden science is a label used to condemn the efforts of researchers and policy decision-makers for their (perceived) disruptive knowledge. When coming from lay people, such labels bring many negative consequences for the scientific-technological progress and innovativeness of societies. Accordingly, in their work researchers and policy decision-makers must consider the state of society's nonknowledge, especially in dissemination activities, to reduce the risk introduced by the label "forbidden science".

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