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RESEARCH ARTICLE

Sociotechnical controversies as warning signs for niche governance

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Abstract
In agriculture, not all sociotechnical niches seek to plant the seeds of further regime transition: Some niches are designed to last as stable subnetworks harboring alternative agri-food systems. However, such niches often interact with sociotechnical regimes, leading to controversies, conflicts, and threats to niches sustainability. This situation calls for proactive governance of niche-regime interactions. We studied the innovation process in the "Corsican clementine" niche, using semi-structured interviews and participant observation. We wondered how local actors have been dealing with three controversial innovations: a clementine variety, a biological pest control method, and a pruning technique. Cross-analysis of the three innovations shows that (i) the niche's innovation pathway can be diverted by regime-driven innovations; (ii) to protect their niche, local actors set collective rules, both formal and informal; and (iii) controversies over technical innovations make niche-regime tensions more visible, leading local actors to make collective decisions for governing the innovation pathway. This study is the first to highlight the key role of sociotechnical controversies in niche governance.

Keywords Agriculture · Geographical indication · Coexistence · Transition · Clementine · Corsica

1 Introduction

In Europe, there is a consensus over the need to speed up the transition to more sustainable agriculture. However, despite proactive policies, significant change in farming practices has yet to be seen (Guichard et al. 2017; IPES-Food 2016). Several studies suggest that desirable changes are hampered by lock-in of the sociotechnical regime (Duru et al. 2015; Meynard and Messéan 2014). A sociotechnical regime is understood as a stable network that frames the evolution of technologies. Regimes rely for their stability on mutual dependencies between actors, alignment between rules of various kinds, and the "hardness" of artifacts and material networks (Geels 2004). In a regime, innovation occurs incrementally, through a gradual accumulation of novelties that synergize with the dominant technology. In agriculture, promising alternative models such as agroecology often fail to upscale, owing to the stability of the sociotechnical regime (Magrini and Triboulet 2012; Stassart and Jamar 2009; Vanloqueren and Baret 2009).

Therefore, several scholars emphasized the need to support the development of sociotechnical niches (Darnhofer 2014; Geels 2002; Meynard and Messéan 2014). Sociotechnical niches are protected spaces where alternative networks design and develop breakthrough innovations. Niches are generally regarded as banks of options for further regime transition. But, in agriculture, niches do not always aim at transforming the regime. Some niches are designed to last, as stable networks sheltering distinctive production and consumption practices (Belmin et al. 2018). European agriculture provides a number of such examples: farmhouse production (e.g., farmhouse bakeries), community-supported agriculture, short supply chains, geographical indications, etc. These niches enrich our agri-food systems since they are sources of diversity: diversity of tastes or of values embedded in products, consistent with each food culture and with emerging consumer demand

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(Vandecandelaere et al. 2009); and diversity of cropping practices, tailored to the constraints and resources of each agro-climatic areas (Duru et al. 2014).

Until now, most studies of agricultural transitions have focused on how niches can emerge and expand to unlock the incumbent regime. In so doing, they leave aside the crucial question of niche stability. This question is important since exogenous innovations can intrude into a niche and undermine its sustainability. Belmin et al. (2018) argue that niches are continuously interacting with the sociotechnical regimes, leading to exogenous tensions (sanctioning of non-standard products by mainstream actors) and endogenous tensions (propensity of niche-actors to align their practices with the standard). If such tensions are not properly managed, a niche can gradually collapse or gradually align with the dominant production model. Maintenance of an endogenous innovation pathway depends on proactive governance capable of mitigating undesirable changes (Belmin and Casabianca 2018).

In agriculture, niche-regime interactions often lead to controversies and conflicts. Discord occurs when outsiders take over the innovations that have been developed in niches, disconnecting them from their ideological foundations (Ingram 2018). The controversies that arise generally oppose two points of view: One side thinks the niche should extend its influence by hybridizing with regime, while the other thinks such expansion is undesirable because it will "conventionalize" the original alternative model. This kind of tension has been described in connection with organic farming (Stassart and Jamar 2009; Teil 2012), permaculture (Ingram 2018), and geographical indications (Belmin 2016; Bowen 2010). In other research fields, some authors have suggested that controversies can play an active role in the governance of innovation (Callon 1981; Joly 2001; Rip 1986; Torre 2016). Controversies reveal the changes taking place in social groups or territories. They force innovation promoters to open the black box of their implicit assumptions and clarify their projects' underlying values. Controversies can also act as catalysts for local democracy: The promoters of an innovation are faced with alternative views about development challenges, and minor stakeholders are brought back into the decision process (Rip 1986).

In light of the foregoing, we wondered what role controversial innovations play in the governance of niches. We assumed that controversies over technical innovations can make niche-regime tensions more visible, leading to changes in the governance of the local innovation process. To test this hypothesis, we studied the way three agronomic innovations have spread in the "Corsican clementine" niche: a clementine variety, a biological pest control method, and a pruning technique. These three innovations generated controversies since they clearly implemented a major breakthrough in the practices. The Corsican clementine niche is a pertinent case study because it interacts extensively with the citrus sociotechnical regime (Belmin et al. 2018).

2 Material and methods

Belmin et al. (2018) described the Corsican clementine production area as a sociotechnical niche that challenges the rules of the table citrus sector. The reputation and value of the Corsican Clementine derive from its small caliber, acidic taste, and green blossom end, contrasting with the large size, sweet taste, and uniform color of the clementines favored by the sociotechnical regime. Moreover, production of Corsican clementines is low (only 20,000 tons per year, vs. 2 million in the case of Spanish clementines, which dominate the European market) and also costly, since it requires selective picking of colored fruits with leaves attached. By contrast, the regime encourages cost-competition and economies of scale. Corsican clementine also enjoys an eco-friendly reputation, as its advertising emphasizes the with-leaf presentation, the freshness of the product and the commitment of farmers in *Agriculture raisonnée*. This French certification scheme attests that farmers optimize their profit while limiting the amount of inputs they use. The niche's main protection mechanism is a Protected Geographical Indication (PGI) created in 2007 (Belmin et al. 2018). The PGI operates via an internal inspection scheme as well as specifications defining a product ideotype (Fig. 1a), target values (within caliber grades 1 to 5, acidity range, and sugar/acidity ratio), and production rules: pre-harvest analysis of fruit acidity, no use of degreening products or other chemicals after harvest, and manual picking of tree-ripened fruits, with at least two harvest rounds.

To analyze the controversies over technical innovations in the Corsican clementine sociotechnical niche, we developed a three-step method: (i) First, we identified the actors involved in the Corsican clementine niche, and we described their functions, strategies, and relationships. (ii) Then, we studied three controversial innovations that are currently being disseminating in the Corsican clementine production area: a clementine variety, a biological pest control method, and a pruning technique. These three cases were selected because they involve different (though sometimes overlapping) groups of actors and different components of the cropping system. For each of these, we tried to understand the innovation process by asking the following questions: In what context, how, and by whom has the novelty been developed and spread? What are the reasons for its adoption or rejection? What are the positions and rhetoric of the various actors with regard to the novelty? What are the underlying visions of technical "progress" that shape their views? (iii) Lastly, based on the study of actor networks and controversial innovations, we sought to understand how niche and regime interact, and how niche-actors manage the tensions generated by these interactions.

Data were collected by various means (Table 1): (i) Open interviews conducted in 2013, during an initial consultation stage with the main representatives of the Corsican citrus area (23 actors interviewed). The aim of this inductive approach was to

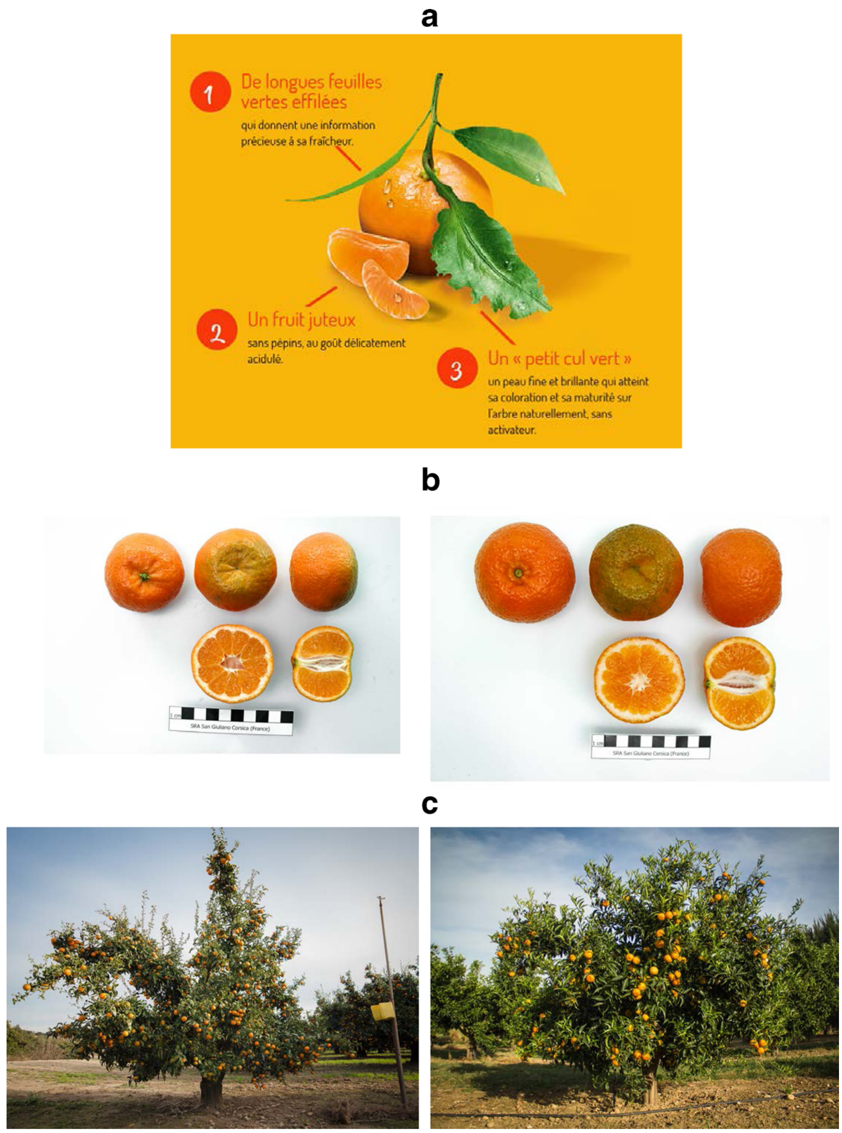

Fig. 1 **a** Ideotype of Corsican clementine used in the marketing of the Protected Geographical Indication. The picture emphasizes the key characteristics of the product: (1) long, green, slender leaves that prove the fruit's freshness; (2) juicy, seedless fruits with a slightly acidic taste; and (3) thin-skinned fruits with a green blossom end, which provides evidence for on-tree coloring and ripening and no post-harvest degreening (© APRODEC). **b** Pictures of the clementine varieties SRA 92 (left) and SRA 535 (right). Scale 3/10 (© F. Curk-Inra). **c** Clementine trees managed with the "long-pruning" technique (left) and by the traditional method (right). With long-pruning, the fruiting branches bend down under the weight of their fruit as harvest approaches (© R. Belmin-Inra)

identify the actors and their activities, identify the main innovations that are currently spreading, and build hypotheses on how the sociotechnical system works. (ii) Semi-structured interviews with 17 farmers, to collect data on the organization of their farm, their cropping practices and underlying drivers and constraints, and their sources of knowledge and inputs. At the end, the farmers were asked why they adopted or rejected each of the three innovations. (iii) Semi-structured interviews with 28 actors involved in the innovation process, conducted between 2013 and 2016. Here, the aim was to understand the different actors' strategies and relationships, and to assess their influence on the ongoing diffusion of these three innovations; (iv) participant observation of various meetings organized by the actors in the Corsican citrus sector. At each meeting, we particularly focused on those statements that revealed the speakers' strategies and the knowledge they were using. We also paid attention to the interplay among actors when dealing with the question of adopting or not each controversial innovation. (v) Collection and analysis of documents, in order to understand what technical information farmers are given, and how agronomic knowledge is constructed in the Research and Development network. These documents included project proposals, newsletters from the local chamber of agriculture, farmers' log books, and PGI monitoring reports. (vi) Analysis of statistical data on the local supply chain.

3 Results and discussion

3.1 The actor networks involved in the Corsican clementine niche

In Corsica, clementines are produced on 139 farms (2013 official figure), almost all of which are in the Corsican clementine Protected Geographical Indication (PGI). Clementine is generally the main crop on these farms, with areas ranging from 1 ha to over 40 ha. Secondary crops include kiwi, grape,

Table 1 Investigation scheme and data sources. Figures in brackets indicate the number of actors interviewed from each organization

Investigation scheme	Data sources
Consultation stage (2013)	Citrus fruit inter-branch organization (1), experimental station (2), regional agriculture support authority (2), organic farming advisory organization (1), farmer organization (2), plant breeder (1), PGI defense and management organization (1), chamber of agriculture (5), citrus fruit research organizations (4), farmers (2), competitive cluster (1)
Farmer interviews (2013 and 2014)	17 farmers, of whom 8 are also packers
Interviews with other actors (2013 to 2016)	Packers (9), marketers (2), organic farming advisory organization (1), chamber of agriculture (2), input supply firm (1), citrus fruit branch organization (1), regional agriculture support authority (1), competitive cluster (1), citrus fruit research organizations (3), union of nursery growers (1), experimental station (1), defense and management organization for the PGI (1), cooperatives (4)
Participant observation (2013 to 2016)	Scientific meetings: Elaboration of the scientific program of the citrus fruit research organization, Project elaboration or implementation meetings for Prospect'Agrum, Innov'Agrumes, and Effibioforce Agronomic meetings: Technical unit, epidemiological surveillance unit. Professional meetings: General meetings of the experimental station, the PGI defense and management organization and the inter-branch organization Public consultations: Regional conference on organic agriculture, meetings to draw up Corsica's rural development program
Analysis of gray literature	Newsletters: irrigation, maturity, soil temperature, plant health (2013, 2014, 2015 issues). Project Proposals: - *Effibioforce*: Tison G (2014) Effibiocorse: Pourquoi le Biocontrôle n'évolue-t-il pas plus malgré son efficacité réelle en Corse? Appel à projets de recherche « Pour et Sur le Plan Ecophyto ». PSPE 2 - Edition 2014. - *Innov'Agrumes*: Froelicher Y (2015) Innov'Agrum. Dossier de demande d'aides européenne, Programmation 2014–2020. - *Prospect'Agrum*: Julhia L, Belmin R, Froelicher Y et al. (2015) Prospect Agrum: Prospective pour la mobilisation des ressources génétiques et la compétitivité des filières structurées autour de labels de qualité - Cas de l'agrumiculture Corse à l'horizon 2030. Réponse AAP CASDAR 2015 Semences et Sélection Végétale. » - *Scientific programme of the citrus fruit research organization*: Delaunay A, Desclaux D, Dessup R et al. (2013) Proposition de projet pour la future Unité Expérimentale de San Giuliano. Rapport interne INRA, San Giuliano, juin 2013. - *Clémentine project*: Belmin R (2013) Projet Bassin de Production Clémentine. Document de cadrage. Corte, Mars 2013. Agronomic trial reports: - Bergougnoux P, Beissy C (2008) Restructuration des vergers de clémentine par la taille longue. Club Expert Agrumes. - Dubreuil N, Leboulanger A (2016) Comparaison de quatre itinéraires techniques en agriculture biologique contre le Pou Rouge de Californie (Aonidiella aurantii). AREFLEC. - Jacquemond C, Tison G, Curk F (2005) Une nouvelle clémentine commune pour la Corse: La SRA 535. Poster communication. San Giuliano. - Leboulanger A, Tison G, Kreiter P (2008) Protection du verger contre le Pou Rouge de Californie (Aonidiella aurantii Mask.). Compte rendu d'essai. AREFLEC
Statistical data	Citrus fruit inter-branch organization

and grapefruit. Several of the larger farms are coupled with packing stations. The work is divided among the farmer's family, a crop manager and permanent and temporary workers. The actor network involved in agricultural support is made up as follows:

– *Marketing network* of packing stations, marketers, wholesalers and cooperatives who collect, pack and dispatch the farmers' crops. Most of the output goes to supermarket chains in France. The marketers play a key role in this supply channel, since they regulate harvests and dispatch.
– *Research, development and extension network*, which disseminates knowledge to farmers and supplies them with inputs. This network is composed of four weakly interlinked sub-networks: (i) input suppliers, who are the farmers' main advisors although unconnected with the other extension actors; (ii) seven cooperatives and one chamber of agriculture; these are mainly concerned with implementing the PGI inspection plan, leaving little room for individual advice to farmers. The chamber of agriculture also disseminates technical newsletters and runs a network of farmers attempting to reduce the use of

crop protection chemicals. This work flows from the Ecophyto plan, a French agricultural policy aiming to decrease the use of pesticides; (iii) an experimental station and an organic farming advisory organization, which are conducting an ambitious research and development project on biological pest control; and (iv) a citrus fruit research organization that investigates the agronomic and physiological determinism of clementine sensorial quality.

- *Network involved in supplying genetic resources* to farmers. Three main actors—the citrus fruit research organizations, the experimental station, and the nursery growers—form a top-down chain from breeder to farmer: genetic resources conservation, phase I varietal creation and plant breeding, phase II plant breeding and graft propagation, distribution of seeds and grafts, and distribution of seedlings.
- *Network involved in niche governance*, which shapes the practices of farmers and other supply chain actors through their support policies (regional agriculture support authority, citrus fruit inter-branch organization) and through the PGI rules (defense and management organization).

3.2 Sociotechnical study of three controversial innovations

3.2.1 A new clementine variety

SRA 535 is a clementine variety with high yield and high caliber potential (Fig. 1b). It has been spreading in Corsica since 2009. As of 2017, the area planted with SRA 535 has reached 75 ha, 5.6% of Corsica's total clementine orchard area. At this planting rate, the variety will cover 389 ha by 2050.

Despite its acknowledged agronomic performance, this variety is worrying an increasing number of local actors. It does not fit the Corsican clementine ideotype as set out in the PGI specifications, i.e., a fruit of "medium caliber" with a "thin peel", a "green blossom end" and a "slightly acidic taste." By contrast, SRA 535 has a majority of large fruits (mainly calibers 0, 1, and 2) and a thick peel. Most actors questioned add that the fruit's taste is different, blander than the traditional variety SRA 92. A marketer testifies: "The taste is significantly different from the usual taste of Corsican clementine". The president of the PGI defense and management organization adds: "The fruits [of SRA 535] are too big, they have too many filaments, it's not Corsican clementine".

SRA 535 is a natural mutation of the clementine tree that was discovered in Spain in the early 1980s. It was introduced in Corsica in 1986, and bred in the 1990s by a consortium including Corsica's citrus research organization and the experimental station. At that time, Corsican clementine was going through a severe crisis caused by Spain's entry into the European common market and the consequent loss of Corsica's monopoly over with-leaf marketing (Belmin 2017; Sainte Marie and Agostini 2003). Corsican farmers, needing to become more competitive, urged local breeders to breed Spanish-type varieties with larger fruits. When the dissemination of SRA 535 began in 2009, the local supply chain had just shifted its strategy to focus on origin-based quality: The PGI had solved the problem of the small size of Corsica's clementines by emphasizing this trait as a heritage attribute.

Despite a broad consensus on the terroir-based strategy, SRA 535 has spread significantly. For good reasons: actors share a common interest in getting larger fruits. European standard CE 1799/2001 defines classes of marketable calibers. Since demand is highest for large fruit, price per kilo increases with fruit size, so the different caliber classes have different market values. In the case of Corsican clementine, calibers 1–3 (the largest fruits) have the highest prices (Belmin et al. 2018). Smaller fruits (calibers 4–6) are less in demand, with low prices and uncertain market outlets. So, it is easy to understand the farmers' interest in SRA 535: Thanks to the high proportion of large fruits, this variety offers substantial prospects for improving their incomes. Moreover, larger fruit are less costly to pick than small ones. As one farmer explains, "It means fewer secateur snips per harvested ton". Caliber is also seen as a criterion of professional excellence: Our surveys clearly show that the "good" farmers are the ones who obtain large calibers on a regular basis. The marketers, for their part, encourage farmers to supply them with SRA 535 for two main reasons. Firstly, marketers are paid in direct proportion to the amount of business conducted, so they have a vested interest in dealing with higher-priced fruit. Secondly, the new variety, because it has fewer small fruits (which are harder to sell), makes for quicker sale of the clementine harvest as a whole. The packers also get a larger margin with high caliber fruits, as they can process more tonnage per time unit. And, the breeders continue to promote SRA 535 as a result of path dependency. For the research organization and the experimental station, rejection of this variety would mean the failure of the 25 past years of breeding work. Since they both participated in building the PGI, they are aware that the high proportion of large fruits is a problem. So since 2002, they have been running agronomic trials (pruning, rootstocks, nitrogenous fertilizer) to "correct what is wrong with SRA 535." Abandoning this variety would also diminish the relevance of the experimental station's accomplishments in other areas of work. SRA 535 is used as a reference variety in various trials (e.g., biological pest control, weed management) to establish technical benchmarks for farmers. With the network of actors so strongly coordinated around caliber, public policies have aligned and strengthened the lock-in: SRA 535 has not only been authorized within the PGI, and its planting has also been subsidized by the regional authorities.

From 2013, when commercial SRA 535 orchards gave their first harvest, a lively controversy arose. (i) Most of the output from SRA 535 ended up at a low price because the PGI specifications exclude caliber 0. So, some farmers started regretting their decision to plant the new variety and said they would return to classic varieties in future. However, it was difficult for farmers to go back, owing to the need for investment return and the prohibitive cost of grubbing-up operations. (ii) SRA 535 was seen by some as a threat to the typicality and reputation of Corsican clementine as its fruits do not fit the Corsican clementine ideotype (medium caliber, thin peel, slightly acidic taste). Accordingly, many actors assume that the overall niche strategy is at risk if SRA 535 spreads more widely. In the opinion of one marketer, the reputation of Corsican clementine would be affected if the area planted to SRA 535 was exceeding a certain threshold: "If everybody grows [SRA] 535, the industry will die. If we only grow little of it, it's OK. But where is the limit? Now, some people are planting half of their orchard space with SRA 535". (iii) The gap between SRA 535 and the classic varieties also generates cognitive dissonance, leading to some passionate reactions. One farmer exclaimed: "I don't want to produce caliber double zero and melons!". However, the PGI gives an unclear definition of typicality (no evaluation procedure for sensorial quality), opening windows of opportunity for a "non-identical twin" to join the Corsican clementine appellation.

Despite apparent unanimity on the PGI, the sociotechnical regime and its caliber injunctions re-emerges through SRA 535. The lively controversy over this variety unveils tensions within the local network of actors, between an objective of higher caliber on the one hand, and the need to maintain the Corsican clementine's typicality on the other.

3.2.2 A biological control method

In the early 2000s, the Corsican citrus orchards were under increasing biotic pressure, with new pests and vectors arriving ever faster. Biological control looked like a promising solution for dealing with the problem in a sustainable way, while at the same time synergizing with the eco-friendly image of Corsican clementine conveyed by the PGI. However, although operational instruments were developed, farmers have not adopted them.

Between 2002 and 2008, a biological control method—the release of *Afytis melinus* to control the populations of Californian red scale (*Aonidiella aurantii* Maskell)—was developed by a research consortium involving the experimental station, the organic farming advisory organization, and the citrus research organization. The Californian red scale is a cochineal scale insect (mealybug) that has been spreading in Corsica since 2003. Its larvae attach to shoots and fruits to suck the sap. The oviposition punctures and the females' shields mark the fruits' peel, making the product unmarketable. To control the pest, farmers use chlorpyriphos-methyl and spirotetramat, two insecticides that have harmful side effects on auxiliary fauna. *Afytis melinus* is a tiny wasp that lives as a parasite on various types of cochineals, including Californian red scale (Hare et al. 1997). Around 15,000–20,000 individuals can be released five to seven times a year, between April and November, as a substitute for chemical pesticides. Trials conducted between 2002 and 2008 proved the efficiency of *Afytis* releases, either alone or combined with other biological control methods.

This tool has been distributed to volunteering farmers since 2009, thanks to European subsidies (Agri-Environmental and Climatic Measure). The Ecophyto plan also supported the use of *Afytis* releases in Corsica, through a scheme called "Réseau Ferme": a group of volunteering farmers agreed to decrease their treatment frequency index (TFI), with the support of the chamber of agriculture. However, since 2013, the area under biological control has remained constant at 160 ha, despite the availability of public financial incentives and the proven efficacy of *Afytis*. To explain this, we need to consider the way the market functions. The EC 1799/2001 standard not only classifies the fruits according to their caliber, but it also grades fruits by their visual aspect, with classes Extra, I and II. To qualify for the Extra class, fruit must be free from defects with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, its quality, keeping quality, or presentation in the package. At the other extreme, Class II covers fruits with defects in shape, coloring, or skin (e.g., silver scales). Lastly, fruits that do not meet the minimum requirements laid down by the EC regulation are not marketable. These include green, under-ripe, rotten, or ugly fruits.

These market categories have major implications. Farmers' incomes depend not so much on the quantity of fruit harvested but rather on the quantity and quality of the fruits dispatched to the downstream market. Moreover, if the percentage of undesirable fruits is too high, the packing stations charge the farmers additional fees for their packing services. At last, marketable fruits are graded by external appearance (classes II, I, and Extra) and the more attractive classes sell at higher prices (Fig. 2). *Afytis* releases only regulate—and do not eradicate—the populations of mealybugs, so some of the fruits' visual imperfections remain (puncture marks, scales). These may be enough to downgrade a fruit batch. Under these constraints, many farmers remain mistrustful of biological control. In their eyes, the use of chemicals is the safest way to limit the quantity of fruits discarded and get a high price for the marketable fruits. In short, the global market's focus on esthetic quality prevents the farmers from shifting to biological control.

Marketers and packers also contribute to the aversion to insect releases. Both ask farmers to keep their orchard pest-free so as to maximize the proportion of fruits in the Extra or Class I categories. For marketers, this is a way to increase sales. For packers, it keeps packing costs low: If an incoming batch is of uneven quality with many unmarketable fruits

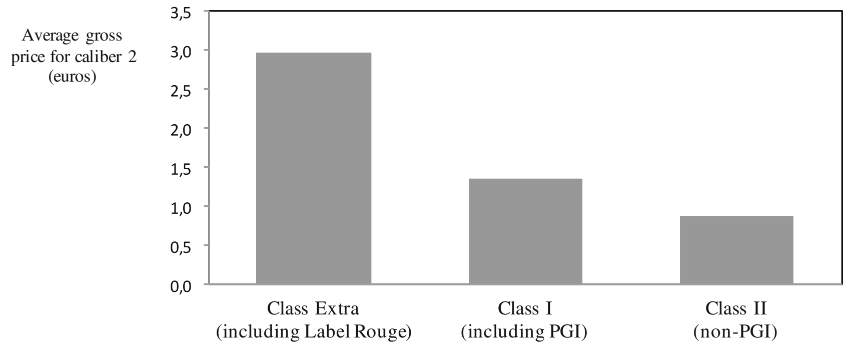

Fig. 2 Average gross price of Corsican clementines for caliber 2 (euros) per category of visual aspect (average of the prices from 2004 up to 2014). Data source: AOP Fruits de Corse

(spots, insect bites, etc.), they have to slow down the passage of the fruit on the sorting table. This leads to narrower margins and shipment delays.

Yet, the PGI specifications commit farmers to adopting greener practices by engaging in France's *Agriculture raisonnée* certification scheme. They also narrow the range of authorized crops protection products. Moreover, the PGI defense and management organization spotlights biological pest control in its marketing materials for Corsican clementine. This may encourage some farmers to adopt this method. But, at the same time, the exclusion of class II fruits by the PGI reinforces the market segmentation based on esthetic appeal. Although grown in Corsica, these can no longer be sold as Corsican clementines; they are sold as "French Origin clementines," their selling price barely covers production costs and they can hardly find market outlets.

In conclusion, the reputation of the Corsican clementine PGI goes hand in hand with exemplary, eco-friendly cropping practices. However, the diffusion of a biocontrol method is hindered because local actors have shared objectives to control the visual quality of the fruit.

3.2.3 Long pruning

In recent years, a controversial method has been gaining influence in Corsica's citrus growing area. This is "long pruning." It consists in pruning the tree severely to obtain just four to six scaffold branches that bear no secondary branches, only young fruiting branches (Fig. 1c). This is in contrast to traditional pruning, where the main branches divide once or twice and numerous secondary branches occupy the center and periphery, giving the tree a uniform shape. Changing from traditional to long pruning involves 1 to 3 years of tree restructuring. Unwanted scaffold branches are removed and secondary branches are also cut off.

Long pruning was first developed in apple, pear, cherry, and apricot orchards in the 1980s. In 2004, an expert from an agribusiness firm showed the method to some Corsican clementine farmers. This expert was introduced by a technical advisor from the local input supply firm, well-known by the farmers. The two technicians organized a training course and set up a trial with a group of six volunteering farmers. The orchards were monitored for three harvest seasons (2005–2007), and it was found that the long pruning gave excellent agronomic results. Building on this first success, the two experts carried other demos and training courses after 2008. New farmers adopted long pruning, and the ones who had already tried it converted their entire orchards.

The spread of long pruning in Corsica has been supported by a coherent technical argument, verified by farmers' observations. The first factor driving its adoption is that it cuts production costs. It improves worker efficiency by making the fruits more accessible: The center of the canopy is empty and there are wide spaces between the branches, opening the way for picking. Moreover, as the harvest approaches, the young, non-lignified fruiting branches bend under the weight of the growing fruits. A farmer who uses the new pruning technique testifies: "In the past, [for harvesting] my workers constantly had to climb into the trees. […]. Now we have reduced harvest costs because there is no longer picking inside the trees, no need for climbing up the ladder: the branches bend down". Costs are also cut by the reduced pruning time. Once the tree has been reconfigured, pruning only consists in removing the older side branches from the scaffold branches. A second factor driving the adoption of long pruning is that it gives fruits of better caliber and better visual quality. According to farmers and technical advisors, this is because with fewer branches, fruits in the lower and central canopy receive more light. "I've been using it [long pruning] for a decade. The trees are doing better. I've had improvements in caliber, yield and earliness. Down there in the trees' skirts, the smallest fruits have got bigger", said a farmer. Long pruning also helps pesticide and liquid fertilizer applications penetrate to the interior of the trees, improving crop treatment efficiency and leading to better control of the pests that affect the fruits' visual appearance.

However, those in favor of reducing or stopping using chemical inputs are strongly opposed to long pruning. They are the PGI defense and management organization, the experimental station, and the organic farming advisory organization. From their viewpoint, because long pruning was developed to improve the penetration of chemical sprays into tree foliage, it nurtures the idea of progress driven by agrochemicals. For other actors (research organizations, nursery growers' association), there is a risk that the trees will decline rapidly. Cutting back the vegetative biomass so drastically may cause an imbalance in growth between the aerial part and the rootstock, "strangling" the tree. Meanwhile, extension officers from the chamber of agriculture and cooperatives warn farmers of another threat: Long pruning may make the trees more vulnerable by increasing the amount of light that penetrate inside the canopy. They think it will cause sun-burn on the main branches and make the tree more susceptible to water stress. They also argue that the pruning injuries caused by the initial tree reshaping facilitate fungal attacks. The president of the citrus fruit inter-branch organization says, "Farmers are sawing their trees into pieces! But at the first fungal attack, the trees die!". More generally, all those opposed to long pruning worry about the lack of hindsight in the transposition of an approach that was developed elsewhere, on other tree species. For them, the rhetoric is seemingly well-oiled but is not based on a knowledge of citrus physiology.

As things stand, nothing can prevent the spread of long pruning within the Corsican clementine niche. The first reason is that the chamber of agriculture and the cooperatives have lost influence. The extension officers of both these structures have significantly reduced their advisory activity because they put most of their time and resources into enforcing the PGI specifications. They are unable to make their voices heard against the competing voices of the input suppliers.

The PGI has played an ambiguous role in the innovation process related to long pruning. On the one hand, it has actively encouraged its use by reinforcing the market rule on the fruits' visual quality (long pruning improves the efficacy of chemical treatment). On the other hand, the PGI embodies informal rules that penalize long pruning. In drawing up the specification sheet, local actors have collectively defined an ideotype for the Corsican clementine orchard as one with small plots of old trees, wedged between sea and mountain. This idealized picture evokes the heritage aspect of the tree. Hence, the definition of typicality provided by the PGI comprises not only the product: It extends to the orchard itself. It is through this prism that niche actors assess the impact of any technical change. In the view of many actors, long pruning foreshadows orchards that do not fit the niche's conceptual foundations: orchards are not "natural" but chemically treated, nor are they perennial, since they are quickly exhausted. That is enough to make a significant part of the local network of actors reject long pruning. But, the PGI specifications do not lay down good pruning practices, so there is no way for the defense and management organization to reject this innovation.

In conclusion, long pruning of clementine trees is successful because it synergizes with farmers' objectives such as lower production costs, larger caliber, and better visual quality. The current controversy over long pruning highlights the tensions between these objectives, and another vision of progress based on agroecology and typicality.

3.3 Cross-analysis of the three case studies

Based on cross-case analysis, we now discuss the importance of controversies over technical innovations for making niche-regime tensions more visible and for improving niche governance.

3.3.1 The sociotechnical regime affects the niche innovation pathway

The sustainability of the Corsican clementine niche depends on farmers achieving both fruit typicality and green cropping systems. Yet, the local innovation process is not shaped only by the niche's functioning; as our study of three controversial innovations shows, the strategies of the farmers and all the other network actors are also constrained by more global rules, stemming from the sociotechnical regime. The various components of the Corsican clementine sector—agricultural production, varietal breeding, research and development, market, norms, and public policies—all converge to seek large, unblemished fruits. This explains why some regime-driven innovations (SRA 535, long pruning) are adopted by farmers, while niche-consistent innovations (biological control) are rejected. The three interlinked components of the sociotechnical regime—rules, actors, and material artifacts (Geels 2004)—intrude into the niche and divert the local innovation process:

> *Rules*—The Corsican niche is not free from the regime's rules. For instance, marketers bring mass-market payment scales into the niche (higher price for large caliber and unblemished peel). This encourages farmers to plant large-caliber varieties and to reject biological control. There are also informal rules. Our case study shows that local actors use regime-driven cognitive frames to judge each other: The good farmer is the one who obtains large, unblemished fruits on a regular basis.
>
> *Actors*—Regime rules guide the development of shared objectives and interdependence among local actors. As we showed in our three examples, there can be no profitable sorting or marketing if the farmers have not managed their crops properly. Strategies reinforce each other, giving farmers no latitude: High-potential varieties, chemical pest control, and long pruning are the best ways to improve fruit caliber and visual quality. Of course, strategies are heterogeneous, and not all actors collude with the regime's rules. But, no one can move too far from it, owing to mutual dependencies. For instance, the PGI defense and management organization is opposed to the spread of SRA 535. But, it is not feasible to change the

PGI rules to prevent the use of this variety: Doing so would exclude the farmers and marketing organizations who have vested interests in SRA 535. The whole PGI scheme would be weakened by losing participants.

Artifacts—Regime rules can also be embedded in technical artifacts that are not easily abandoned. In the Corsican clementine niche, many material investments have been made to comply with the regime's rules. For instance, packers have built sorting stations in order to sell batches with uniform caliber and spotless fruits. But, these material investments carry embedded rules that hinder niche emancipation: Efficiency in the packing stations is proportional to the diameter of the incoming fruits. The hardness of material artifacts is also a powerful source of path dependency. Local breeders spent two decades developing SRA 535. The aim was to align with the Spanish model at a time when the niche was weak. Today, this variety is recognized as a threat to the niche strategy. But, breeders cannot easily go back on their decision: The breeding process for trees is very slow, and SRA 535 is now used as a model in agronomic trials. For their part, the farmers who regret having planted SRA 535 are faced with prohibitive grubbing-up costs.

3.3.2 Niche functioning mitigates expression of the regime's rules

Regime rules penetrate the niche, but local actors are not passively compliant. The innovation process is also framed by a set of place-specific rules enacted by niche-actors. As Belmin et al. (2018) demonstrated, the Corsican clementine niche embeds a coherent set of rules that accumulated over time under the influence of the island's natural features and resources, and were formalized in constructing the PGI. As the cross-case analysis suggests, this locally embedded rule system acts as a "filter" to innovations stemming from the regime. In other words, the functioning of the niche mitigates expression of the regime's rules at the local level. Building on Scott (1995), we identify three types of rules that provide a counterweight to the regime:

Regulatory rules: Some of the formal rules in the PGI specifications directly hinder the adoption of innovations that threaten typicality. For instance, the exclusion of caliber 0 from the PGI acts as a powerful "call-back mechanism," reducing the incentive to use SRA 535.

Normative rules: The niche also conveys shared values and responsibilities that help to shape the niche-actors' strategies. In particular, because of the added value that a protected origin brings, local actors manage the clementine's typicality and reputation as common goods. This explains why some actors reject the regime-driven innovations, while others reshape them to synergize with the clementine PGI (selecting rootstocks so as to reduce fruit size in SRA 535). Similarly, the commitment of Research and Development actors to biological control is fostered by the eco-friendly reputation of the Corsican clementine.

Cognitive rules: The niche filters innovations coming from the regime by means of stabilized concepts, narratives, and idealized images that shape local actors' perceptions. These cognitive frames developed over a long period and were later clarified when the PGI was drawn up. Thus, the value of SRA 535 and long pruning respectively is assessed in the light of ideotypes of product and orchard. Even if they fit the PGI specifications, the novelties that are too far from the "local norm" generate cognitive dissonance and may be objected.

3.3.3 The active role of controversies in niche governance

There are limits to the niche's regulatory capability. The regime creeps in through every breach in the niche's defense mechanisms. This is obvious with the atypical variety SRA 535, which was able to gain a foothold in the appellation because of the loose definition of varietal type in the PGI. Similarly, long pruning is allowed by the imprecise specifications on pruning in the PGI. Finally, it has been spreading because the advisors from the chamber of agriculture and cooperatives were not on the spot. They were distracted from their advisory role by their key role in enforcing the PGI. In our second case study, biological pest control is making no clear progress because Class II fruits are excluded from the PGI.

In the Corsican case, the controversies arising from the various innovations play an active role in niche governance: They have helped local actors to identify the tensions between niche and regime and to take regulatory action. After the PGI came into operation, the threat of crisis receded and, as a result, collective action weakened; from 2007, the defense and management organization settled into a routine, running on autopilot. Then, in 2016–2017, because of the issues raised by the three controversies, local actors conducted a participatory forward study. They built five scenarios describing possible futures for citrus production in Corsica in 2040. The threats and opportunities entailed in the scenarios led to discussions about possible revision of the PGI specifications. In particular, participants mentioned possible ways to hinder the spread of SRA 535 (exclusion of caliber 1 from the PGI, elaboration of sensory benchmarks to describe the typicality of Corsican clementine) and ways to improve the product's environmental credentials (general shift to organic farming, inclusion of the Class II fruits in the PGI). They eventually decided on a change in supply chain governance: They have broadened the remit of the citrus fruit inter-branch organization, devising a new commission tasked with providing a strategic long-term vision. In short, the outbreak of controversies acted as a trigger, stimulating the niche-actors to formulate the problems caused by niche-regime interactions and make a change in niche governance.

Science and Technology Studies scholars have shown that technological controversies (also called "sociotechnical controversies") can play an active role in the governance of innovation (Callon 1981; Torre 2016). Controversy is an informal process through which new technologies can be assessed (Joly 2001; Rip 1986). By expanding the framework of risk assessment for any novelty, controversy forces innovation promoters to open the black box of their implicit assumptions and clarify their projects' underlying values. This widens the range of possibilities and choices. In some cases, all this can lead to a new consensus and renewed governance of the local innovation pathway (Rip 1986). Although our study is not part of Science and Technology Studies, its findings are consistent with that body of literature. We argue that, in the Corsican clementine niche, controversies are the process through which (i) regime-driven innovations are assessed (and sometimes reshaped) in the light of the niche's rule system. This has been the case with SRA 535 and long pruning; (ii) niche-actors raise the alarm when innovations that are consistent with their niche are hampered by the regime. This was mainly the case for biological pest control. All this suggests that the sustainability of niches lies in the niche-actors' ability to take advantage of sociotechnical controversies. In this respect, Research and Development organizations have a key role to play. By studying the controversies over technical innovations, they can shed light on the regime's influence over the within-niche innovation pathway and so contribute to proactive governance of niches. For a simple, pragmatic method, one could take the approach used in this article. It consists in a four-step analysis: *Step 1*—identify the technical innovations causing tensions among niche-actors (preliminary survey of the main niche representatives) and becoming controversial; *Step 2*—for each controversial innovation, search for the drivers that stimulate or hinder adoption by farmers (systematic survey of farmers); *Step 3*—study the competing discourses, strategies, and networks surrounding each controversial innovation (surveys of the actors involved in the sociotechnical niche); and *Step 4*—identify the various shared rule systems that coexist locally, and the loci of friction between two contrasting sociotechnical systems.

3.4 A niche nested within the regime

Sociotechnical niches are usually regarded as isolated networks that emerge outside regimes. Indeed, most scholars speak about "niche-actors" and "regime-actors" (see an example in Darrot et al. 2014); when analyzing niche-regime interactions, they implicitly assume the existence of two distinct networks working in different directions, two groups of actors that either ignore or use each other (Ingram 2015). For instance, niche-actors can use the regime's internal tensions and enlist hybrid actors (Diaz et al. 2013; Geels and Raven 2006). But, in our case, niche-regime interactions take a different shape. Our findings show that there is no separation between the networks of actors that reproduce the rules of the niche or that of the regime. In fact, each actor has an ambivalent strategy. Farmers have to make trade-offs between contradictory objectives since there is a mismatch between what the regime expects and what collective reputation requires. So, Corsican clementine cannot be regarded as an isolated niche. On the contrary, it is nested within the citrus sociotechnical regime. On the one hand, the niche conveys locally embedded rules encouraging local actors to maintain the product's typicality. On the other, some of the regimes' rules apply within the niche, encouraging the use of varieties or techniques that are not consistent with the functioning of the niche. So, the distinction between niche-actors and regime-actors is not relevant here. Rather, we have to distinguish between antagonistic rule systems that are enacted and reproduced through the everyday practices of local actors.

The idea of a "nested niche" is not completely new. It has been implicitly put forward in mainstream transition theory, although largely ignored by those who use that theory. According to Geels (2011), sociotechnical niches, regimes, and landscape are not necessarily distinct networks: They represent various levels of the structuring of human activities, involving increasing number of actors. In other words, the three levels coevolve and participate together in shaping actors' practices. Moreover, niches are described as spaces where regime rules are not entirely absent but are only weakly articulated (Geels 2004). This is precisely what is going on in our case study: The regime's rules intrude into the niche in a debased form because the niche's functioning mitigates their expression.

This new perspective on niche-regime interactions opens a promising field of investigation. Alternative food systems are popping up all across the world, on the fringes of the dominant agro-industrial food system (Esnouf et al. 2013). Whether driven by environmental, ethical, health, or heritage concerns, these alternative food systems are spaces where small networks of actors invent new ways of producing, consuming, and exchanging. However, alternative and conventional food networks are not separate spheres (Sonnino and Marsden 2005). By analyzing alternative food systems as sociotechnical niches nested within mainstream regimes, we could gain an interesting insight into their complex relationships.

4 Conclusion

Agricultural niches often take the form of alternative agri-food systems with endogenous innovation pathway. Such niches are major sources of diversity for agriculture and food worldwide. However, niches can collapse if they are intruded upon by regime-driven technical innovations. To prevent the niche from reverting to the regime's rules, local actors have to improve their management of niche-regime interactions.

In this paper, we have wondered to what extent the technical innovations that are subject to controversies can shed light on the weak spots of niche governance. To answer that question, we analyzed the conditions under which three controversial innovations spread in the Corsican clementine niche: a clementine variety, a biological pest control method, and a pruning technique. Our cross-case analysis suggests that controversies make niche-regime tensions more visible, leading local actors to make collective decisions for governing the innovation pathway. This is the first study to highlight the key role of sociotechnical controversies for understanding and managing niche-regime tensions.

These results suggest that Corsican clementine cannot be considered as an isolated niche. On the contrary, this niche is a subsystem partly nested within, and partly free of, the citrus sociotechnical regime. This point puts a new perspective on coexistence in agriculture. Past studies had described systems that coexist side by side, like genetically modified/non-genetically modified crops (Hannachi 2011) or organic/conventional agriculture (Belz 2004). Here, we point out that sometimes, one system can be nested within another. The rule systems for niche and regime coexist at the local level since they compete within the same network of actors. This new perspective could question the basic nature of transition for agricultural sociotechnical regimes. Until now, a transition towards more sustainable agriculture has been understood as a monolithic regime shift, through transformation, reconfiguration, technological substitution, and/or de-alignment/re-alignment (Geels and Schot 2007). Yet, in agriculture, things seem to take a different shape. There is now a global movement towards market segmentation, driven by the emerging consumer demand for products with environmental, ethical, health, or heritage qualities. Could this trend stimulate a new type of transition, in which a regime slowly fragments into several insular "productive worlds" that interact while each follows its own innovation pathway? If so, such transitions would be interesting to study.

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