Article

SUSTAINABILITY, INNOVATION AND RURAL DEVELOPMENT: THE CASE OF PARMIGIANO-REGGIANO PDO

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Abstract

Sustainability, as well as a concept related to a development model, is becoming a real guide to drive the governance choices of value chains. A sustainable policy has the objective of perpetuating production models over time while maintaining the environmental, economic and social dimensions that characterize a given production process. It is therefore important to measure the sustainability of a production system in its environmental, social and economic components and to understand the ongoing trends under the pressure of agricultural policies, market dynamics and innovation pattern introduced along the time in a production system. The purpose of the article is to assess the evolution of the level of sustainability of Parmigiano Reggiano production system under the effect of 20 years of innovation mechanism which impact on product quality, value chain performance and rural development. To this aim the paper discuss a holistic framework that allows the representation of stakeholder's role considering the value chain and the territorial dimension. The paper discus also the use of dimensional indicators and propose a use of synthetic indexes to provide an overall picture of the evolution of sustainability of specific production system.

Keywords: sustainability, innovation, local agri-food system, rural development.

JEL Q13; Q16; Q18.

1. Introduction

Sustainability is a very complex concept conceptualized by FAO as the set of three areas linked together and identified in the environmental, social and economic dimensions [1]. Therefore, the aim of a sustainable production should take into consideration all the inputs (natural and social resources) that contribute to the creation and the valorisation of food products along the time. A particular attention should be given at the protection of the natural and social resources in order to let them be reproducible in the long-term. In doing this, the people of rural areas involved in the production systems will be able to continue their activities in their regions. This is also the aim of the Rural Policies that aim to improve the quality of life for all the rural population both engaged in farming and non-farming activities.

The aim to define a sustainable development become complex when innovation is introduced and when become a relevant driver for economic growth or when face technical or social problem. To this regards FAO, with the purpose to promote sustainable local agricultural products, has develop the concept of "Virtuous quality circle" [2] which suggest the codification of natural resources and production techniques in order to manage the reproduction of the system along the time. The impact of innovations is particular relevant for Geographical Indications (GIs) since they act both on the Value Chain and on the territory where the inputs are produced and processed [3] [4]. Inputs usually present specific quality features and processing attitude while the processing phase reflect the culture of the producers on the base of their capacity to adapt their process at the local environment [5]. Value Chains represent not only the evolution and the trajectory of a products but embody the complex system of relationships among agents from production to consumption. The concept of value chain combines the technological functions of the supply chain in a more economic and managerial actions. The value chain, especially in the agri-food sector, is regarded as a production management tool useful to create proper product quality levels and develop marketing strategies aimed at creating value for all the actors of the chain [6].

The structural characteristics and the dynamics of the value chain, however, are not sufficient to assess the impact on the sustainability of GI production systems whose efficiency is the result of the "embedding condition" between the value chain and the territory that give the name to the GI. To better understand the determinants of the sustainability of GI systems become useful the definition of a theoretical framework which provide a key of interpretation of the environmental-social-economic domains where actors and stakeholders develop their strategies for producing, trading and consuming the GI products.

The scientific debate around the role of the territory in terms of its contribution in enhancing the level of economic competitiveness often describes Industrial District (ID) [7] as the most efficient industrial organisation model. ID offers a model of production that can help small and medium sized enterprises (SMEs) to attain the same level of competitiveness as large firms and thus contribute to economic growth and social development [8]. The same concept is also useful to observe and evaluate the sustainability of the production system that, in turn, coincides with the territory.

A useful conceptualization of the interaction between the territory and the value chains are the Local Agri-Food System (LAFS). LAFSs concept are similar to the concept of IDs, since they are considered as a multi-dimensional concept, able to raise the competitiveness level of the territory by forging opportunities in a sustainable logic. Hence, LAFSs and IDs represent models of economic growth, social development and environmental management. Their main characteristics are the link with the territory in all its dimensions, including not only its environmental, social and economic aspects, but also the role played by all the typologies of territorial agents (i.e., environmental, economic and social) and their managing institutions by governance marketing strategies, local resources and specific environmental characteristics. Three distinctive features identify a LAFS:

i. the place: intended in its broadest meaning, as used by the French school "*terroir*", it covers the specific nature of natural resources, the production history and tradition and the presence of local know-how [9] [10] [11] [12];

ii. the social relationships: which consist of trust, reciprocity and co-operation among actors; they are the "glue" of local action and an endogenous development mechanism can arise from the interaction with place [13];

iii. the institutions: private and public agents who promote actions regulated by formal and informal rules [8];

LAFS can take different forms, depending on the role that the natural environment, the agricultural sector and the food industries have in the production process and in managing the whole system [3]. The way in which agri-food systems reorganise themselves, meet consumer needs, generate positive (or negative) externalities and trigger spatial dynamics, is a cause, rather than an effect, of the evolution process. The interaction among LAFS's stakeholders is then a central point when defining the evolution process of the

local system considering the link between the territory and the food chain. The scheme of possible combinations between food chains and territories leads to different typologies/classes of agri-food systems [3]:

i. The Closed System: local agricultural outputs are processed by local food industries (mainly SMEs), and purchased by local consumers. This typology is characterized by a strong and unique link between agricultural production and the processing phase, companies and/or the local consumers with a great impact on product quality, firm structure, market strategies and relationships with the environment.

ii. The Open System: agricultural outputs are not processed by local food industries or purchased by local consumers. This typology is characterized by value chains where the upstream and downstream actors may not solely belong to the territory. This happens whenever the local supply doesn't satisfy the demand of input from the factories and when local consumption is not able to completely absorb the output convincing the LAFSs to look for larger markets. Moreover, in "open" LAFS models, local companies might benefit from connections with local and non-local research systems, which allow them to innovate and follow new technological paths, raising their level of competitiveness without losing the link with local traditions.

iii. The Mixed Systems: coexistence of close and open LAFS. These systems are characterized by the coexistence of both "closed" and "open" LAFS models. The territory at the same time has specific natural characteristics and develops strategies that are typical of both ID and rural districts. The outcome of this combination is the reinforcement of meanings of all the variables that characterize and influence the development process of local areas, including reputation. Nevertheless, problems can emerge between the group of producers if they have different strategies and different views in the use of local natural resources [26].

When LAFS include the value chains present the feature of "closed" production system the local environment is the most critical aspect since the reproduction of natural resources and reinforcing the image and the reputation of the entire system contributes to producing inputs and the volume of production at the specific quality level. The characteristics of local resources become then relevant, since they are not just linked to environmental characteristics (e.g., land and water), but also to those aspects, like biodiversity, animal breeds, and local tradition, with high specific features associated with the history and the natural environmental conditions of the region. Their specificity, thus, is in contrast with standardized resources, which are "generic" and reproducible by definition and characterizes the quality of the final product and contributes to defining the local food quality [14], [15].

Moreover, when agri-food systems generate public goods, all the sustainable dimensions of LAFS become part of the territorial asset [16], [17] since the quality of food is closely linked to quality of the environment and the quality of social relationship among actors. Hence, the LAFS becomes a suitable dimension for interpreting economic changes and strategies within a rural community of citizens and entrepreneurs involved in a process of cumulative knowledge, where economic actors specialize in the production of certain types of goods (or services), which satisfy the needs (or desires) of citizens and consumers inside and outside the local area, with such logic of sustainable development. Besides, unlike local development, rural development includes natural resources as active components of the production systems, and their evolution should be carefully managed in order to avoid future drawbacks related to environmental issues, volume of production, quality and sustainability of the whole system.

In conclusion, the enhancement of local products through the activation and capitalization of tangible and intangible assets, which includes social capital and natural resources, may allow a fair remuneration and, therefore, the re-production of the LAFS by encouraging the preservation of the territorial system with regards to the social, economic and environmental dynamics. On the contrary, inadequate remuneration of local resources, especially labour, negatively impacts on the production systems by modifying the technologies, increasing the human pressure, reducing the intrinsic quality of final products and the reproducibility of the system.

It becomes clear how the sustainability of GI systems depends on a close relationship between value chains and territorial institutions. The link between the two institution, which manage respectively the value chain and the territory, guarantees its sustainability acting on the natural environmental dimension combined with the cultural and social dimension relative to the ability to interact with specific environments. It is possible argue that there is a "cause-effect relationships" between the strategy of the LAFS actors and the impact on the economic, environmental and social sustainability variables of their decisions.

Evolution of GI systems is then related to all the elements that are the result of the governance process both at corporate, collective and policy level, including to innovation. This latter, especially in LAFS, change the relationships among local inputs and the sustainability of the whole system. Indeed, an ex-ante analysis is essential in order to catch and describe the potential, and the impacts, over the all dimensions of sustainability both on the value chain and on the area of production.

Having in mind all these aspects the assessment of the impact of innovation on the sustainability of GI system require to define: i) a holistic approach for the assessment of sustainability, which include the definition of the indicators and a methodology for their normalization; ii) the definition of the area of analysis (the LAFS); iii) the definition of innovations that put the sustainability of LAFS under pressure.

The objectives of this paper is to assess the impact of innovations on sustainability of a GI system by using the H2020 Strenght2Food methodology. The case study under analysis is the Parmigiano Reggiano cheese. The paper will be organised as follow: i) the description of the methodology, ii) the description of the innovations that were introduced during 20 years; iii) the assessment on the sustainability level presenting the indicators and iv) the discussion of the overall results.

2. Materials and Methods

The theoretical framework to assess the impact of innovation on LAFS

The theoretical framework adopted in the present research follows the Local Agri-Food System (LAFS) approach which enables to consider both the chain structure (farming and processing) and the territorial dimension where the innovation will generate environmental, social and economic impacts. For each level, the analysis consists of two steps: i) the definition of the sustainable variables; ii) the size of the impact of those innovations on the geographical indication (GI) system.

A list of indicators aiming to describe the impact on sustainability was developed in the EU 2020 Strenght2Food project starting from the approach proposed by the Food and Agriculture Organization of the United Nations (FAO): the sustainability assessment of food and agriculture systems approach (SAFA). The SAFA approach aims at describing the economic, social, governance-related, and environmental impacts of agricultural and food systems, with a list of over 100 indicators computed on a self-assessment basis. SAFA isolates 21 themes and 58 sub-themes covering the four above-mentioned dimensions [18]. The Strenght2food project is using 23 indicators grouped by the contribution given to sustainable development in the environmental, social and economic aspects of the production of several food categories. Unlike the SAFA method, the Strenght2Food indicators evaluate the sustainability of LAFS. For this reasons, some indicators are defined and computed both at farm level and at processing level of the value chain, while others are specific of the rural areas within the GI Region. This approach is providing an indirect measure on the sustainability of the territory linked to the production of the respective food productions.

All the indicators used in the Sstrenght2food project are the result of a specific elaboration [19] based on the use of primary data, as specific to the case study and found by field research, and secondary data according to available databases.

As in the SAFA philosophy, sustainability was identified and defined according to three classes of externality: environmental, social and economic, assuming that each innovation generates an impact on one (or more) of these three dimensions. To the aim of this research the main assumption is that innovations and governance generate a cross-cutting-effect on all the three sustainable dimensions. Thus their impact

can be observed by the definition of a baseline and its evolution by the time of the introduction of new innovations and related governance actions. This paper will focus only on the impacts generated in the province of Parma (which is one of the provinces included in the Code of practice), both on the chain and on the rural area differentiate by altitude.

The amount of inputs and outputs related to the Parmigiano Reggiano value chain was assessed as research activities of the Strenght2Food Project. Specifically, economic (Ec), environmental (En), and social (So) indicators were computed on the basis of primary and secondary data collected in both field and desk analyses [18]. Differently from the research on Strenght2food, this research considers only a set of indicators from Strenght2food (mainly economic indicators) related to the supply chain, to which are added other indicators that are intended to describe the structure of the agricultural supply chain (farms and dairies) and rural areas differentiated by altitude in the years 2000 and 2018. To this regard some variables are common for all the agents while others are differentiated by altimetry, moreover some variables refer to the value chain dimension, while others refer to the territorial dimension.

The aim of these variable is to describe the main economic, social and environmental impacts that are observed at different level of the LAFS system. Economic and Social information originated by different sources available at NUTS 4 Level as Italian FADN (for economic information), the register of milk producers managed by Region Emilia Romagna (for structural information), the statistical portal of Province of Parma (for all the social information) [20], while Environmental information are originating from the Strenght2food elaboration [21]. The goal of territorial information is to describe how the different rural areas of the Province of Parma react to the pressure of the evolution of the population, the markets, the agricultural policies, the social policies and the introduction of innovations. As described in the next paragraph, some innovations enter in the Parmigiano-Reggiano system directly from the market without any filter, while for others the Parmigiano-Reggiano Consortium carries out its regulation action by introducing rules that regulate its use. As detailed in Table 1, all the variables reflect the LASF feature but some variable are differentiated by altitude while others are differentiated by Value Chain and Region. The first one reflects the feature of specific area, while others reflects the role of the value chain or the region in the definition of economic, environmental and social impacts.

Table 1: - Variables for the assessment of the impacts of sustainability

Type of sustainability	Label	Variables	Description	Altitude differentiation	Value Chain and regional differentiation
Economic	Ec_vc1a	price	EUR kg-1 (cheese)	any	value chain
	Ec_vc1b	gross value-added	% of turnover	any	value chain
	Ec_vc1c	gross margin	% of turnover	any	value chain
	Ec_vc2	Agricultural structure	ha/n. farm	plane / hill/ mountain	value chain
	Ec_vc3	productive structure	n. cow / n. farm	plane / hill/ mountain	value chain
	Ec_vc4	production capacity	milk produced (t) / n. farm	plane / hill/ mountain	value chain
	Ec_vc5	milk productivity	milk produced (t) / n. cow	plane / hill/ mountain	value chain
	Ec_vc6	work productivity	milk produced (t) / n. AWUA	plane / hill/ mountain	value chain

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	Ec_vc7	industrial structure	processed milk (t) / n. dairies	plane / hill/ mountain	value chain
	Ec_re1	local multiplier	Euro	any	regional
Environment	En_vc1a	green water footprint (net consumption of water)	m3 kg-1	any	value chain
	En_vc1b	grey water footprint (water pollution)	m3 kg-1	any	value chain
	En_vc1c	blue water footprint (gross consumption of water)	m3 kg-1	any	value chain
	En_vc2	production pressure	n. cow / UAA	plane / hill/ mountain	Regional
Social	So_re1	anthropic pressure	(inhabitant/kmq^2)	plane / hill/ mountain	Regional
	So_re2	total employment	total employed / resident	plane / hill/ mountain	Regional
	So_re3	industrial employment	industrial workers / residents	plane / hill/ mountain	Regional
	So_re4	agricultural employment	agricultural workers / residents	plane / hill/ mountain	Regional
	So_re5	senility		plane / hill/ mountain	Regional
	So_vc1	Social aggregation	n farms / n. dairy	plane / hill/ mountain	value chain

Source: authors' elaboration

The economic variables aim to catch the main significant information that describe the structural and the economic evolution of the Parmigiano Reggiano production system (price, value added, operational margin, farm and dairy structure, farm production capacity, farm productivity). One interesting economic index is representing by the "*Local Multiplier3 (LM3)*", which is the only economic indicator at territorial level, enables to calculate the local economic impact generated by the dairies operating in their municipality [19], and more in specific how many Euros rest in the area of production for each Euro received by the market. The environmental variables are focusing only on two aspects: the use of water and the pressure of farming system due to the intensity of breeding system. By the contrary the social indicators are referred mostly to the territorial level. They catch how the local population behave with respect the anthropic pressure, the work opportunities and the capacity to generate/attract youth in their municipality; in this indicators is considered also the social role of the Parmigiano Reggiano grouping farmers in the same dairy (especially if they are coop).

The objective of the use of indicators is to set benchmarks that can be updated in order to provide useful information to agents and stakeholders and help them to managing both the value chain and the rural policy, to producing externalities and to reproduce the Parmigiano-Reggiano Local Agri-Food Systems.

Each indicator reports different impacts and in a multi criteria logic can be showed individually (as SAFA and Strenght2Food suggest) or can be combined into a single composite indicator. Both approaches present advantages and disadvantages in relation to the objective of the analysis. To the aim of this research is used the approach of composite indicator which allow to represent a synthetic state of the sustainable dimension providing elements for an evaluation also by non-expert and policy makers.

Composite indicators are, by definition, multi-dimensional and are intended to describe a complex system of different phenomena captured by single dimensional indexes. The problem (and the solution) of aggregation different indexes and dimensions is similar to the one adopted by the United Nations Development Program (UNDP) in computing the Human Development Index (HDI), which combines the dimension of a long and healthy life with the access to knowledge, and a decent standard of living. In the present study, the challenge was how to treat and how to calculate a "comprehensive" sustainable index which aggregates single indicators representing the different sustainability dimensions. For the purpose of this research the definition of composite indicators on sustainability, the following steps are adopted:

i. definition of "*dimensional index*": it is the indicator which report the observed value with respect the deviation from others values from others homogeneous observations. It is calculated as:

$$\textit{Dimensional index} = (\textit{actual value} - \textit{minimum value}) / (\textit{maximum value} - \textit{minimum value}) \quad (1)$$

The dimensional indexes are normalised using a quantitative scale from 0 to 1, where 0 represents the lowest level (i.e. the lowest impact on sustainability) and 1 the highest. The normalisation was made in order to obtain comparable indexes (unit less indexes), on one hand, and to summarize them in aggregated indexes, on the other hand. To pursue the first aim, the indicators were simplified and grouped into environmental, social and economic.

ii. definition of an "*aggregate synthetic index*" through a geometric mean value:

$$\textit{Synthetic index} = (\textit{Dimensional index 1} * \textit{dimensional index 2} * \textit{dimensional index 3})^{1/3} \quad (2)$$

Literature reports several methods of weighting and aggregating indicators according to the purposes, the scales, and the perspective adopted [22]. For the purpose of this research the method adopted was aggregation through a geometric mean. This is in line with the purpose of assessing the state of a particular production, as pointed out by Gan *et al.* [22], although we also rely on a strong sustainability perspective [23], [24]. The choice of relying on a strong perspective, rather than on the weak one, reflects the idea that all dimensions contribute equally to the sustainability generation and locates the study in the research line which takes into account other dimension besides the purely economic one [24].

Consequently, in this research, after a focus group with a representatives of stakeholders, was used the same weight (score 1) among indexes and, to avoid compensability among the dimensions, only a geometric aggregation method was utilized. In fact, using a multiplicative function instead of an additive one, the indicators are not compensated. We thus proceeded by computing one aggregated index per category and then, following the same method, one general sustainable aggregated index.

3. Results

3.1 The innovation process in the Parmigiano Reggiano LAFS

LAFS is not a static system but subject to the pressure of internal and external dynamics to the system. Usually the evolution of a system is considered in the light of changes in market conditions driven by the evolution of input and output prices. However, although the Parmigiano Reggiano system is highly regulated through the code of practice, technical progress also modifies and influences the evolution of the system by acting directly and indirectly on the sustainability of the value chain and the production territory. Somehow technical progress acts in parallel with the evolution of the market and rural policies, becoming, together with the governance of the value chain one of the tools to improve business resilience

The theme of the ways in which technical progress, considered in a broad sense, is addressed by the system of GIs is particularly relevant [25], [26] [27], as it implies changing the rules between producers, potentially favouring someone and disadvantaging others, and some institutional steps at national and EU level related to the change in production regulations. It follows that in the GI system the introduction of innovations (generally of an exogenous nature to GI) is potentially the cause of conflicts between the agents of the value chain and the GI-Consortia intervene by regulating their use and acting directly or indirectly

on the potential impact on the production system [27] of the LAFS. It follows as relationship between innovation and LAFS implies several levels of analysis: i) innovation and the GI value chain, in which the value chain is made up of operators who manufacture the GI; ii) innovation and consumer perception; iii) innovation and territory; and iv) innovation in governance action in GI-LAFS [27].

The analysis of the impacts of each individual innovation becomes extremely difficult as innovations often act simultaneously on multiple dimensions of sustainability and on multiple levels of the value chain. Nevertheless, the impacts must be measured and analysed to understand their "aggregate effect" and if the governance policies are appropriate with respect to the proposed objectives.

In this respect the Parmigiano Reggiano system, or rather the relative LAFS, offers an interesting case study as: i) Parmigiano Reggiano cheese (and its territory) is a product with a long history but with a slow and progressive evolution; ii) as GI the Parmigiano Reggiano is strongly regulated in the technical and managerial aspects through three different internal regulations: milk production, cheese production and use of marks; and iii) the GI Consortium carries out a strong governance action for the entire production system including the adoption of innovations.

Is probably unknown that innovations in the Parmigiano-Reggiano LAFS have occurred since the Middle Ages, but were largely unrecorded until the 19th century. In 1861, after the unification of Italy, cheese trade increased and modern practices were introduced first at the trade level, and later at the processing level. When internal customs barriers in Italy were removed, PR producers faced problems in keeping product quality standards high. At that time, eleven small dairies from Bibbiano (Reggio Emilia) producing high-quality cheeses based on good pastures for cows and on the skill of local cheesemakers started to show their wares at exhibitions and trade fairs in Italy and abroad [28]. At the end of the 19th century, the Animal and Cheese-making School of Reggio Emilia introduced a whey starter into the production process to cope with enduring quality problems [29].

Considering the "sui generis era" (just before the introduction of the Reg. 2081/1992 until today) at least 34 different innovations were introduced (Table n. 2) and have worked concurrently in the LAFS (some innovation impact simultaneously on different levels). This feature show as, in principle, the EU Regulations on GIs do not stop the technical progress. Are the producers themselves that decide which innovations can or cannot be adopted in light to the capacity to respect some rules that are considered fundamental. In the case of Parmigiano-Reggiano, the "golden rule" is to produce cheese without any type of preservative except salt. All the innovations must respect this fundamental feature and vice versa innovation that require the use of preservatives in the production of cheese are not allowed.

For the purpose of this research, a tentative to organise the innovations implemented in the Parmigiano Reggiano LAFS focus only on two dimension: i) innovation typology: organizational, process technological innovations, product technological innovations; and ii) innovation impacts: product quality, Rural Development, value chain competitiveness. This segmentation provides a clear picture of possible impact that each innovation can generate (Table 2).

Table 2: innovation per type category and impact. From 1990 to 2018

	innovation impacts			
innovation typology	**Product Quality**	**Rural Development**	**Value chain Competitiveness**	**Total**
Organizational	**11**	**4**	**7**	**22**
Casein plate (traceability)	1		1	2
Delimitation of packaging area	1			1

Heifers from production area		1	1	2
ISO 9001 introduced in some cheese dairies			1	1
Labelling rules (from 10 to 12 month maturation time)	1			1
Maturation temperature rules	1			1
Milk payment on quality basis			1	1
Milk quota to "milk for PR " quota	1			1
Packaging in the PR production area		1	1	2
Product Definition of production area specifications for farms	1			1
Product promotion and communication	1	1		2
Product specifications for dairies	1			1
Product specifications for maturing and quality check	1			1
Protected Designation of Origin (PDO) (1992)		1	1	2
Protection of PDO logo and Consortium brand			1	1
Quality segmentation rules by labelling	1			1
Third party certification body	1			1
Technological innovations process	**5**		**7**	**12**
Cooling of the storage rooms	1			1
Feeding with hay			1	1
Mechanical harvesting			1	1
Mechanical milking			1	1
Milk cooling	1			1
Packaging technology spread			1	1
Pre-packed grated cheese, portions for snacking, PR as ingredient	1			1
Product segmentation	1		1	2
Robot for cheeses cleaning			1	1

Spread of lorries with refrigerated milk tanks	1			1
Unifeed feeding system			1	1
Technological innovations product	**5**		**1**	**6**
Analysis of preservatives and fat content by certification body	1			1
Feed composition	1		1	2
Hygienic norms as to bacteria content in milk	1			1
Hygienic norms of equipment for transportation and processing	1			1
Microbiological and chemical analysis	1			1
Total	**21**	**4**	**15**	**40**

Source: authors' elaboration from [27]

Almost 50% of innovations introduced in the LAFS was aimed to increase product quality. They consist, on the one hand, of technological process or product innovations such as hygienic norms or processing rules to assure that the product is safe for health: hygienic regulations for equipment for transportation and processing, regulations on bacteria content in milk and microbiological and chemical analysis. These innovations reduced the amount of lower quality cheeses, by reducing bacterial levels in milk, defects in cheese and moisture loss. The economic impact is estimated around 300,000 euros per year [27]. On the other hand, they concern technological process and organizational innovations related to marketing strategies as new packing and consumption models: vacuum packing of pieces of cheese or packaging sizes for "ready to eat" cheese (e.g. snack portions, cubes, shavings) increased significantly in the period 2013-2015; agreements between CFPR and food companies for co-branding to meet new types of demand grew from 150 to 200 between 2015 and 2016 [30], [31], [32]. The co-branding of this innovative product brought added value deriving from the synergy between the reputation of the two brands and the taste preferences of two types of consumer [30].

Twelve percent of innovations impact indirectly on rural development. These all are organizational innovations such as the Parmigiano Reggiano Consortium (CFPR), the PDO designation and regulations that protected local production and processing (eg. Heifers from production area, packaging in the PR production area). The CFPR represents a major institutional innovation, with the aimed to guarantee the quality of the product, to protect the reputation of Parmigiano Reggiano against fraud and usurpations and provide consumer guarantees on the credence attribute of "origin" [33]. It introduced, decades before EU legislation, the objectives and the tools of Regulation 1151/2012 ("Quality Package") that gives the "ex-officio" protection in EU from miss uses and usurpations of the designations. At the same time, it establishes the role of Protection Consortia in terms of trade, thus recognizing the actions taken to safeguard producers' incomes [27].

Thirty percent of innovations impact on value chain competitiveness. They are mainly organizational innovations and technological process innovations. Organizational innovations are related to: the definition of production areas on farms, definition on packaging area, milk payments based on quality and traceability, to protect consumers as well as farmers from unfair competition by other farmers; international ISO norms and other retailer quality certifications were adopted to provide stability to product batches, thus facilitating the sale of the cheese; Parmigiano-Reggiano "cheese quotas" that have been introduced by

the Parmigiano-Reggiano Consortium in 2015 to replace the EU milk quotas and protect the farm asset and representing a value for farmers [27]. Technological process innovations, such as mechanical harvesting, mechanical milking, robot for cleaning cheese cut working times and labour force requirements. Others, such as new packing and product segmentation, allowed longer shelf life, without compromising the core characteristics of the traditional Parmigiano Reggiano cheese [27].

All the innovations interact on different levels of sustainability at the same time. They can have a positive or negative impact and act directly or indirectly. In this paper the effect of innovation will be catch by the index described above. They provide a proxy of synergic effect produced by the interaction of different type of innovation on the LAFS system at environmental, social and economic levels.

4. Discussion

The assessment of the introduction of the set of innovations with the Parmigiano Reggiano system sustainability, was conducted on two different historical moments 2000 and 2018: just after the introduction of the EC Regulation 2081/1992 on GI and after few years the conclusion of the EU milk quota system.

Parmigiano Reggiano is one of the best known PDO Italian cheeses in the world. Its quality depends on a severe Code of Practice (CoP) which regulates milk production and its transformation into cheese in a defined production area (five provinces in Emilia-Romagna and Lombardy regions) as well as the ripening system and the use of logos in commercial activities. In the Parmigiano Reggiano system, natural factors play a central role in typifying the final product. The protection and careful management of the natural resources thus represent an important phase enabling the survival of the uniqueness of the product. For this reason, alfalfa still today is a substantial proportion of the diet of the animals.

The cultivation and the use of this forage guarantees a good level of animal welfare, and impacts positively on natural resources as well as landscape maintenance. The Parmigiano-Reggiano cheese is still considered an artisanal product since the cheesemaker still play a fundamental role in defining the quality by his knowledge and ability to manage lots of milk produced (potentially) in different natural and managerial contest. Moreover, the social role of Parmigiano-Reggiano is fundamental by the capacity to aggregate farmers in the same dairy. They are not only "supplier" but trough the Parmigiano-Reggiano system they become also managers and create a strong social link among producer that, often, are spatially isolated in rural areas. The analysis concern only the Province of Parma that, nevertheless, in the milk campaign of 2018 represent the area with the higher number of dairies (150 out of the total of 330 dairies) and the higher numbers of cheese-wheels produced (1.286.000 out of the total of 3.699.000 cheese-wheels) [34].

Most of the dimensional index of sustainability, in the aspect of environmental, social and economic indicators was assessed within the Strenth2food Project, others were specifically elaborated for the purpose of the research. The evaluation has been carried out focusing both on the value chain and on the territory where the production system is set, in line with the Local Agri-Food System concept. Reflecting the approach described above, the assessments by synthetics index is presented in Table n. 3.

Table 3. Observed value per sustainable indicator, year and Value chain level

Indicators	Name	Sign	Unit	Value for FQS at farm level		Value for FQS at processing level	
				Year 2000	Year 2018	Year 2000	Year 2018
Economic indicators							
Ec_re1	Local multiplier	+	Euros	2,4	2,5	2,4	2,5

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Ec_sc1a	Price	+	EUR kg-1 (cheese)	0,4	0,5	9,0	9,3
Ec_sc1b	Gross value-added	+	% of turnover	65,0	54,9	7,3	7,8
Ec_sc1c	Gross operating margin	+	% of turnover	63,0	52,5	2,3	2,6
Ec_sc2_h	Agricultural structure	+	Ha/n. Farm	12,7	18,1		
Ec_sc2_m				8,9	13,8		
Ec_sc2_p				14,5	21,6		
Ec_sc3_h	Productive structure	+	N. Cow / n. Farm	38,7	84,1		
Ec_sc3_m				21,5	51,5		
Ec_sc3_p				49,5	99,0		
Ec_sc4_h	Production capacity	+	Milk produced (t) / n. farm	228,5	498,2		
Ec_sc4_m				124,9	304,4		
Ec_sc4_p				296,9	591,8		
Ec_sc5_h	Milk productivity	+	Milk produced (t) / n. cow	5,8	6,0		
Ec_sc5_m				5,7	5,8		
Ec_sc5_p				6,0	6,0		
Ec_sc6_h	Work productivity	+	Milk produced (t) / n AWUA	1,2	2,1		
Ec_sc6_m				3,1	6,5		
Ec_sc6_p				1,5	2,7		
Ec_sc7_h	Industrial structure	+	Processed Milk (t) / n. dairies			2.103	2.512
Ec_sc7_m						2.317	2.498
Ec_sc7_p						1.777	2.551
Environmental indicators							
En_sc1a	Green water footprint (net consumption of water)	-	m^3 kg-1	4,80	4,33		
En_sc1b	Grey water footprint (water pollution)			0,65	0,51		

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En_sc1c	Blue water footprint (gross consumption of water)			8,80	7,33	58,0	51,5
En_sc2_h	Production pressure	-	N. Cow / UAA	0,66	0,75		
En_sc2_m				0,47	0,43		
En_sc2_p				0,80	0,83		
Social indicators							
So_re1_h	Anthropic pressure	+	inhabitant/km²	139,1	165,2	139,1	165,2
So_re1_m				22,4	20,7	22,4	20,7
So_re1_p				167,4	202,0	167,4	202,0
So_re2_h	Total employment	+	Total employed / inhabitant	45,6	45,4	45,6	45,4
So_re2_m				37,1	41,7	37,1	41,7
So_re2_p				45,7	43,4	45,7	43,4
So_re3_h	Industrial employment	+	Industry employed / inhabitant	20,6	17,5	20,6	17,5
So_re3_m				15,8	15,5	15,8	15,5
So_re3_p				20,4	16,9	20,4	16,9
So_re4_h	Agricultural employment	+	Farming employed / inhabitant	2,8	3,0	2,8	3,0
So_re4_m				3,5	3,9	3,5	3,9
So_re4_p				3,6	3,3	3,6	3,3
So_re5_h	Senility	-	Index number	181,8	159,3	181,8	159,3
So_re5_m				416,2	408,2	416,2	408,2
So_re5_p				178,0	155,5	178,0	155,5
So_vc1_h	Social aggregation	+	N farms / N. Dairy			9,4	6,0
So_vc1_m						18,6	9,4
So_vc1_p						6,0	4,3

Source: S2F and authors' elaboration

The description of the phenomena detected by the observed data for the economic, environmental and social indicators, give us a rather complex image due to the different intensity of the observed phenomena and the direction of the latter. Considering the economic indicators, for example, it is observed that the

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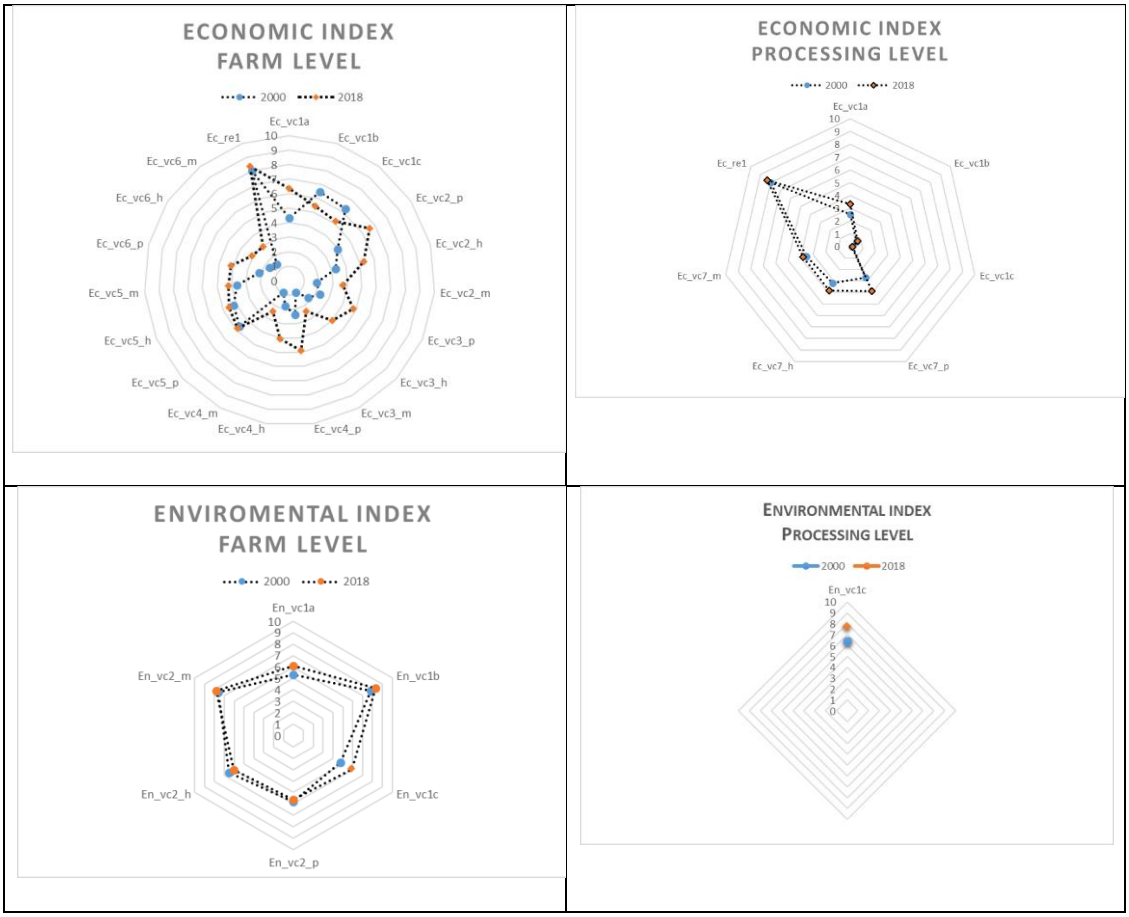
gross value-added and the gross operating margin, decrease for the agricultural companies (even if in modest measure) while they increase for the dairies. This phenomenon is linked to the reduction of the commercial weight of dairies cooperative which by their nature must transfer the profit to farms, and to the increase in dairies non-cooperative which, on the other hand, produce a profit for the company. Farms have reacted with a classic "economy of scale" strategy: increasing both the structure (Ha / Farm) and the capacity (cow / farm) production. Similarly, dairies have also adopted a scale strategy, significantly increasing their industrial structure (processed milk / dairy). These phenomena reflect on the environmental dimension not so much in the use of water (which is reduced), but in the productive pressure (n. Cow / Ha) which increases in the plains and, above all, in the hills. Just the hill areas are those that indicate a greater dynamism than the plain and the mountain. On the other hand, the latter is the area with the most critical evolution of social indicators and manages to guarantee employment only thanks to the use of services. However, the most alarming aspect is the sharp reduction in the indicators relating to the social aggregation of the value chain of Parmigiano Reggiano (n. Farms / dairy) which in the mountains are reduced by 50% (from 16.6 to 9.4).

It is objectively difficult to grasp the dynamics described above for a non-expert given the number and the dimensional characteristics of each variable. The use of dimensional indicators facilitates the reading and interpretation of the phenomena that affect the overall sustainability of the system. The transposition of the dimensional indices by graphs provides an even clearer indication than described (Table 4).

Table 4. Dimensional index per sustainable indicator, year and Value chain level



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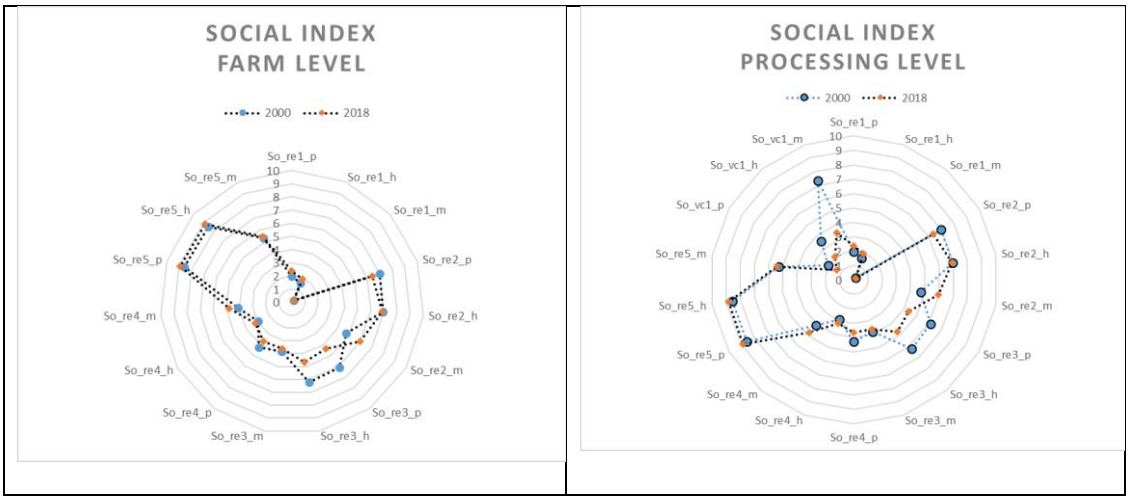

Source: authors' elaboration

As shown in Table 4, the description of the indicators by means of normalized indices provides an immediate interpretation of the evolution of the production system from a SYAL perspective, highlighting the evolution of the variables that directly refer to the value chain with respect to those that describe the characteristics of rural areas. In the case of Parmigiano Reggiano it clearly shows how sustainability is due to the incidence of economic and environmental variables, to the detriment of social variables. This result is not surprising as the innovations that have been introduced have two main aims: i) to increase the competitiveness and resilience of the system; ii) optimize the management of the production process along the supply chain in a "labour saving" key.

Aggregation through the logarithmic scale, as suggested by Gan [22] and Stigliz [24], provides an even more concise reading of the evolution of the system, indicating how overall economic and environmental sustainability has improved, but not social sustainability (Table n.5)

Table 5. Synthetic sustainable indexes per year and Value chain level

Synthetic indexes	Farm level		Processing level	
	2000	2018	2000	2018
Global Synthetic index	3,21	4,02	2,58	2,49
Economic Synthetic index	2,71	4,38	1,75	2,08
Environmental Synthetic index	6,21	6,56	6,40	7,71
Social Synthetic index	3,74	3,72	3,75	3,39

Source: authors' elaboration

5. Conclusions

The methodology of multiple normalized indicators provides a picture of the level of sustainability of the Parmigiano-Reggiano system which highlights how the effect of innovations, together with the evolution of the markets, the structure of the production system and the territory, is not neutral.

The increase in technological and organizational pressure on the Parmigiano-Reggiano system strongly influences its evolution by changing its characteristics. On a scale of 1 to 10 the synthetic sustainable index

in the year 2018 is only 4.0 for farms and 2.5 for dairies. This value is justified by a good level of environmental sustainability (above 6 and improving) due above all to the low production pressure that characterizes the Parmigiano-Reggiano system as a whole. The index value highlights how the technological innovations introduced allowed more sustainable management of natural resources reducing negative environmental externalities.

Economical index increase at both upstream and downstream level. That indicates that technological product and process innovations have a positive impact on the value chain, especially at farm level, whose index increase from 2,72 to 4,38 between 2000 and 2018. Indeed, the CFPR policy aimed at supporting farmer's income protecting their activity and giving value added to the raw material. On the contrary, at dairies level emerge a lower economic sustainability since dairies, that are mostly coop, are instrumental in the valorisation of milk. Nevertheless, the economical index increased from 1,75 to 2,08 at dairy level in the same period.

The social dimension of sustainability shows to be the weakness component of the Parmigiano-Reggiano LAFS. In this index are include indicators which catch the social evolution of the rural areas. The decreasing values of social sustainability is linked to the social evolution of the rural area and the fact that, from one side, agriculture (included the Parmigiano-Reggiano producers) has introduced massive technologies labour saving and, from another side, is not anymore the main socio-economic activity of the region. Indeed, the social index, that includes sociodemographic territorial index, decreased from 3,74 to 3,72 at farm level and 3,75 to 3,39 at dairy level between 2000 and 2018. Nevertheless, the number of milk farmers per dairy strongly decreased in that period, impacting in a negative way to the aggregated social index.

In conclusion, these values show acceptable sustainability conditions between 2000 and 2018 and catch the capacity of the system's ability to react to the increasing technological pressure and market competition. It is difficult to imagine a return to "labour intensity" processing techniques, but we can think of how LAFS evolves by offering commercial services (such as direct sales), or recreational tourism to consumers / tourists who might be attracted to these areas. This last scenario, although desirable, is not easy to achieve and requires the strategic sharing and collaboration of all the stakeholders that animate the LAFS.

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