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**ORCID**
GI: 0000-0001-9780-9962
GS: 0000-0002-9286-7810

# The evolution of organic market between third-party certification and participatory guarantee systems

Gianluca Iannucci[1], Giovanna Sacchi[2,*]

[1] *Department of Economics and Management, University of Florence, Firenze, Italy*
[2] *Faculty of Science and Technology, Free University of Bozen-Bolzano, Bolzano-Bozen, Italy*
*Corresponding author. E-mail: giovanna.sacchi@unibz.it

**Abstract.** Quality assurance is a dominant feature of organic production and, currently, third-party certification is recognized as the official authenticity assurance strategy by the majority of worldwide organic regulations. This model, however, is less accessible to smallholders because it is costly and its application time-consuming. Furthermore, this certification system has been accused on several fronts to be responsible for the standardization of the organic production process leading to a "conventionalization" of organic productions. Contextually, in several countries, groups of small producers have started to implement alternative quality assurance systems for their organic products, better known as Participatory Guarantee Systems. Research to date has not yet determined how these models can survive within a highly competitive market such as that of certification. In this framework, the paper aims to theoretically unveil and explain the alternative certification phenomenon and its coexistence with third-party certification by applying an evolutionary game (rationally bounded agents that adopt the more rewarding strategy). The results of simulations suggest that symbolic attributes such as localness, healthiness, quality, producers and consumers embeddedness can differentiate products guaranteed by alternative schemes, meeting consumers' preference. The discussion of findings provides an assessment of the performance of both quality assurance systems, explain their coexistence within the organic market, identify critical aspects, and suggest some policy implications.

**Keywords:** organic market, certification system, Participatory Guarantee Systems, Evolutionary Game.
**JEL codes:** C73, O13, Q01, Q12, Q13.

## 1. INTRODUCTION

Recent trends in the analysis of organic food led to a proliferation of studies closely related to the process adopted for ensuring the integrity and authenticity of organic products (Hatanaka et al., 2005; Vogl et al., 2005; Zorn et al., 2012; Bauer et al. 2013; Janssen and Hamm, 2014; Veldstra et al., 2014). The mainstream approach is the so-called Third-Party Certification





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(TPC) which plays, among others, an important role for consumers in proving organic food authenticity. In general terms, in TPC an independent private body verifies the production process of a good and independently determines if the final product complies with organic standards. The verification typically includes comprehensive formulation/material reviews, testing as well as facility inspections. If the verification obtains a positive assessment, products bear the right of the organic logo usage on their packaging that can help consumers and other stakeholders to make oriented purchasing decisions. Currently, many organic regulations worldwide adopt TPC as their official authenticity assurance strategy (National Organic Program of USDA, European Union Council Regulation (EC) No. 834/2007, Japanese Agricultural Standards, Australian National Standard for Organic and Biodynamic Produce, etc.). In several developing countries organic-certified products have been growing in recent decades with the purpose of being exported to European and North America markets (Ayuya et al., 2015) gaining a price premium. Furthermore, TPC is beyond question less accessible to worldwide smallholders, both in terms of the big amount of time required to the accomplishment of the paperwork, and in economic terms because of its costs (Harris et al., 2001; Milestad and Darnhofer, 2003; Vogl et al., 2005; Courville, 2006; Eernstman and Wals, 2009). Finally, it has emerged a debate on the evidence that certification and standardization of organic production have led to unintended consequences towards a new form of governance (Guthman, 2004; Vogl et al., 2005; Courville, 2006), from the movement-oriented to the market-oriented organic production practices. In the same vein, other authors argue that the standards set by the organic regulations brought to a "corporatization" of organic agriculture (de Lima et al., 2021) which threaten the original principles of the organic movement of health, ecology, fairness, and care towards a more process-based production system. In other words, and according to Courville (2006), "Paradoxically, the regulatory systems that were developed to protect the integrity of organic agriculture including standards-setting and conformity assessment systems are now reshaping the organic landscape in ways that threaten many of the values held by the movement that created it." (p. 201).

In the attempt to cope with these problematic issues, in several countries, groups of small producers have started to implement "alternative" quality assurance systems for their organic productions. There are two main alternative certification and guarantee systems to TPC, better known as Internal Control Systems (ICS) and Participatory Guarantee Systems (PGS). ICS, or Group Certification, "was originally created to increase equity and access of smallholder to certification schemes" (Pinto et al., 2014, p. 60). It consists in the development of cooperatives, associations, or networks of farmers that voluntarily adhere to common organic production standards (usually based on national regulations). Afterward, an independent certification body verifies the process functioning as well as a limited number of randomly selected companies/farmers. The results of the inspection, in both positive and negative cases, affect the whole group. Adopting such a quality assurance scheme simplifies certification procedures for smallholders, who are often unfamiliar with all the paperwork required for third-party certification requests. In addition, it is more affordable compared to the mainstream certification model. ICS is used primarily by smallholders of developing countries willing to access the markets of developed countries for the price premium advantage linked to organic production (Latynskiy and Berger, 2017).

On the other hand, according to the official IFOAM definition, PGS are "locally focused quality assurance systems. They certify producers based on the active participation of stakeholders and are built on a foundation of trust, social networks, and knowledge exchange" (IFOAM Official definition, 2008). IFOAM Organics International provides further details by describing such initiatives as "a verification system to ensure that a produce is organic. It is an alternative to third party certification for organic products, especially adapted to local markets, small farmers and short supply chains. They allow certified organic produce to be available to a wider consumer group, at a lower cost". Also, "PGS initiatives involve groups of farmers and groups of consumers; they are normally supported by an NGO or local association that provides the participants with administrative and technical help" (IFOAM Organics International).

To the best of our knowledge, the PGS approach has been widely observed empirically, nevertheless, a theoretical framework or a modelling effort suitable for the interpretation of these phenomena is still missing in the academic international literature.

In this perspective, the present paper aims to propose a mathematical modelling framework by using the Game Theory approach to assess and explain PGS model, in the attempt to shed light on its coexistence within a highly competitive market such that of certification. Examples of evolutionary games application do exist in academic literature. Indeed, thanks to its adaptability, the evolutionary context has been applied to several topics as well as to environmental economics and agricultural markets (Antoci and Bartolini, 2004; Antoci et al., 2013; Blanco and Lozano, 2015; Antoci et al., 2019).

On the contrary, its application to organic market and organic certification represents a novelty which allow us to a) analyse the evolution of the share of PGS firms within the organic market; b) study the bounded rationality of small firms which usually characterize organic market (Bonfiglio and Arzeni, 2020); c) present some implications on the market composition due to the comparative dynamics performed by changing parameter values of the model.

The reminder of the paper is organized as follows: Section 2 provides an overview of worldwide PGS development, the main features and functioning mechanisms as well as an outline on academic literature focused on these initiatives. It then will go into presenting the model in Section 3, its dynamic regimes in Section 4, while Section 5 provides a discussion of the main economic results together with some policy implications. Finally, in Section 6 conclusions are drawn.

## 2. PARTICIPATORY GUARANTEE SYSTEMS FOR ORGANIC PRODUCTS

The pioneering experiments that led to PGS development date back to the 1970s and were linked to a growing interest towards agroecological principles in general (Altieri, 1987; 1995) and organic agriculture in particular.

The first communities of organic producers consisted of family farmers and small companies interested in methods of production aimed at the promotion of social and environmental sustainability. The achievement of their objectives implied the development of a strategy to make their products recognizable to consumers.

These communities have been growing over the decades, stimulating a great debate around the need to formalize their work and their alternative actions in both developing and developed countries. In 2004, the first International Conference on Alternative Certification was organised by the International Federation of Organic Agricultural Movement (IFOAM) and the Latin American and Caribbean Agro-Ecological Movement (Movimento Agroecologico de America Latina y el Caribe, or MAELA) in Brazil.

Although different methodology could be applied and norms and processes might vary, the key features of PGS remain consistent worldwide. In general terms, PGS are usually based on the IFOAM International Organic Standards, and they require the involvement of *all* actors within the production process and along the supply chain (from producers to consumers) by taking place at the community level. A PGS model aims at minimizing bureaucratic procedures and costs (in economic terms) by employing simple verification methods. It also incorporates elements of environmental and social education towards quality improvement for both producers and consumers. The basic common elements of several PGS initiatives are the following: i) a participatory approach; ii) social control; iii) a shared vision and shared responsibility among stakeholders regarding quality, transparency, trust building, and reinforcing mechanisms; and iv) a non-hierarchical relationship between stakeholders (Fonseca, 2008; IFOAM, 2008). Furthermore, a key feature of PGS models relates to the close relationship between producers and consumers, or co-producers. The process, in fact, involves direct selling allowing the reduction of transaction costs. In this way, as also experienced by Fair Trade practices, producers obtain a higher price by decreasing the numbers of middlemen, and this effect decreases contextually the price of organic products, with a positive impact for the final consumers. In a sense, in absence of an alternative procedure for quality assurance, in most cases, the possibility of access the (local) market is excluded to disadvantaged and/or small producers (Nelson et al., 2010; IFAD, 2004) and it also threatens the possibility of purchasing organic products by potential local consumers. In other words, the mission, and at the same time the challenge of PGS, is favouring and facilitating smallholders' production towards the promotion of local food systems that meet agroecological principles, biodiversity protection, workers' rights, and an easier access to organic food.

These schemes are quite popular in less developed countries such as Brazil, India, and Costa Rica, but there are also several cases of PGS adoption in Western countries like the United States, France, New Zealand, and Italy. The most famous networks adopting PGS are the Brazilian Rede Ecovida de Agroecologia, Certified Naturally Grown (USA), Nature et Progrès (France), Keystone Foundation (India), Organic Farm NZ (New Zealand).

Recently, the IFOAM has developed a navigable map sponsored by the Food and Agriculture Organization of the United Nation (FAO) which records worldwide PGS initiatives. Figure 1 reproduces a static image of it.

Through this map, it is possible to find PGS projects at a global level, as well as the number of producers certified by PGS schemes by different countries. The yellow pointers define self-declared PGS initiatives (operational or under development), the green ones PGS projects officially recognized by local authorities, while the blue pointers define PGS models recognized by IFOAM. According to the data collected in 2019 by IFOAM (IFOAM Global PGS Survey, 2019), at least 223 PGS initiatives have been recorded at a global level. These projects involve about 567.142 farmers and spread over 76

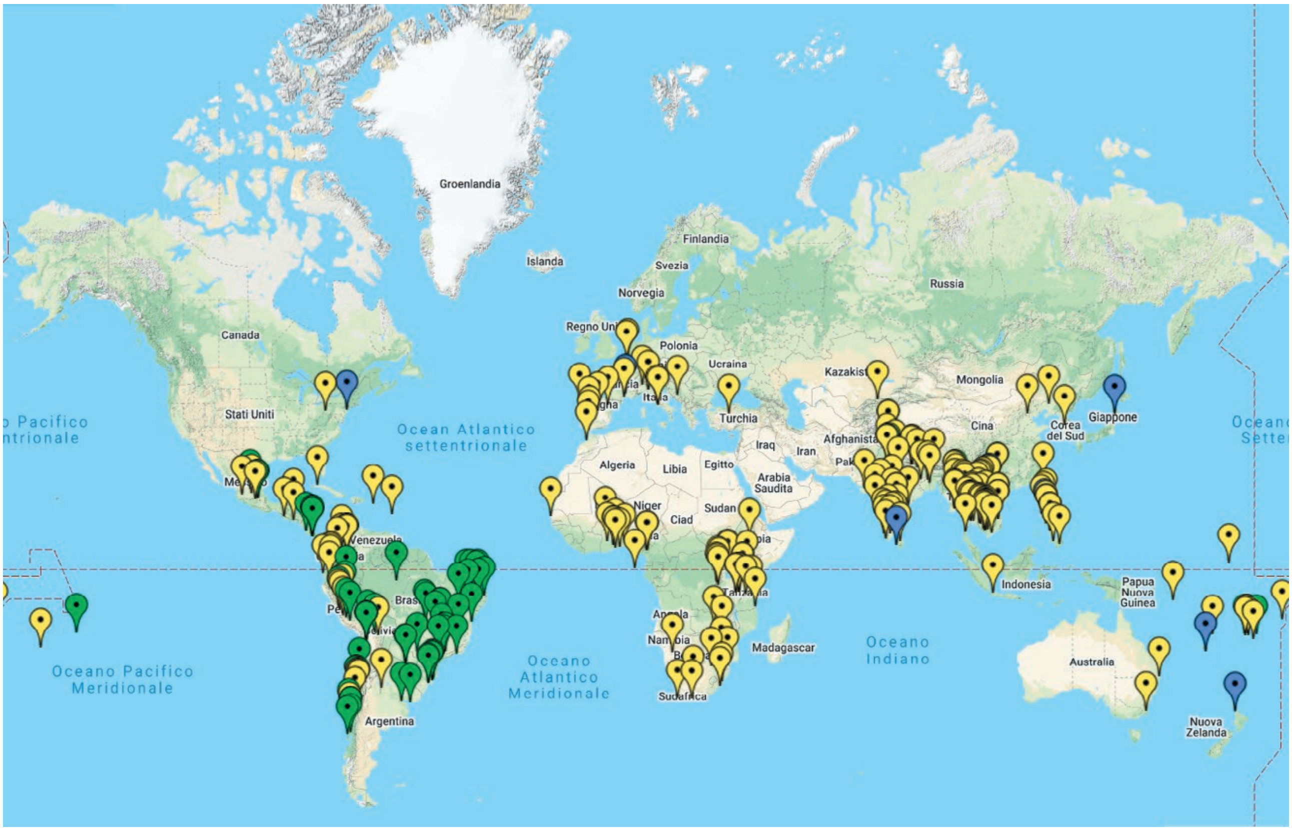



**Figure 1.** Worldwide PGS distribution. Source: IFOAM website (https://pgs.ifoam.bio/).

countries. Since the submission to the IFOAM Global survey (and the consequent registration within the IFOAM database) is on a voluntary basis, it is reasonable to assume that the numbers reported are underestimated (Sacchi, 2015; 2019). In some cases, PGS initiatives (such as the Brazilian and French ones) are older than national organic regulations, establishing third-party certifications as the official guarantee system, and in some countries (especially in Latin America) PGS are officially recognized in national organic regulations and, in these cases, PGS are also defined as Participatory certification.

But how do PGS function in practical terms?

Usually, farmers are organized into local groups that have the responsibility to ensure that all participants adhere to the PGS principles and processes. Each farmer receives an annual visit at least by one peer, namely another farmer/breeder/bees keeper of the group pertaining to the same product category. Other stakeholders, such as consumers, technicians, support staff of NGO, can join, and they are encouraged to do so, the peer during the visit. Results of these visits are documented and serve as the basis for the group of farmers to take decisions on the certification status of each network member. A summary of the documentation and the outcome is communicated to a higher level, for example, to a National or Regional Council. The Council approves/denies the certification decision taken by the groups or, more generally, allow/reject the use of the PGS logo, if any, to each local group.

As far as academic literature is concerned with PGS phenomenon, it mainly focuses on producers' motivation in PGS adoption (Zanasi et al., 2009; Binder and Vogl, 2018; López Cifuentes et al., 2018; Kaufmann and Vogl, 2018; Fonacier Montefrio and Johnson, 2019), on social innovation, empowerment and spill-overs effects deriving from PGS adoption (Home et al., 2017; Rover et al., 2017; Sacchi, 2019; Lameilleur and Sermage , 2020), on issues linked to consumers attitude and behaviour towards organic products guaranteed by PGS (Sacchi et al., 2015; Kaufmann and Vogl, 2018; Sacchi, 2018; Carzedda et al., 2018) to institutional matters (Fonseca et al., 2008; Nelson et al., 2010; Loconto et al., 2016; Cavallet et al., 2018).

As mentioned above, what is currently missing is a mathematical theoretical model able to capture PGS worldwide initiatives to understand how such systems can survive within the organic market competing with third-party certification.

## 3. THE MODEL

The model considers the existence of a food organic market composed by a n-size population of firms that assure the authenticity of their organic productions following two possible modes. The first one consists in delegating the certification to a third-party body and paying a certification cost (TPC firms); while the second mode implies the adoption of participatory guarantee strategies (PGS firms).

We assume perfect competition; therefore, farms compete choosing the level of output. Furthermore, we assume that the market is horizontally differentiated. Consumer has a unique reservation price but there is a certain degree of substitution between the goods that determines different output prices (when it is lower than 1). Finally, the third assumption of the model regards the slope of the marginal cost of PGS farms that is greater than the slope of the marginal costs of the TPC farms, therefore produce using PGS mode is more expensive. These assumptions have been introduced for the following reasons:

1) perfect competition is a standard way to model food market,
2) horizontally differentiation can capture a price differentiation between goods (without assuming higher quality from one good, as in vertically differentiation), and
3) the PGS standards can be more stringent than TPC.

Finally, we endogenize the choice to adhere to PGS or to TPC introducing a dynamic selection process, the replicator equation, given by the evolutionary game theory. At each instant of time, farms can revise the mode or adopt a new one, following the differential profits that allow to compare the two strategies[1].

Denoting PGS and TPC firms with subscripts $i = g$, $c$ respectively, and assuming their profit functions as follows:

$$\pi_g = p_g q_g - \frac{e_g}{2} q_g^2$$
$$\pi_c = p_c q_c - \frac{e_c}{2} q_c^2 - \phi q_c \tag{1}$$

where $p_g$ and $p_c$ are the unit prices of the good produced by PGS and TPC firms respectively, $e_i>0$ is the slope of the marginal cost, $q_i$ represents the quantities produced, and $\phi>0$ is the certification cost ($\phi q_c$ is the total certification cots). To consider the higher effort of PGS firms in favour to the environment and workers' rights, as well as to non-financial costs linked to participation, engagement to association, time and efforts to manage visits to peers, it is assumed that $e_g>e_c$.

The market is horizontally differentiated[2], and therefore, it has a unique reservation price and consumers substitute the goods at a certain degree (see, for further details, the seminal work by Spence, 1976)[3]. Denoting with $x\in[0,1]$ and $1\text{-}x$ the shares of PGS and TPC firms respectively, the inverse demand of the goods produced by the firms is given by the following linear functions:

$$p_g = \bar{p} - xnq_g - \alpha(1-x)nq_c$$
$$p_c = \bar{p} - (1-x)nq_c - \alpha xnq_g \tag{2}$$

where $\bar{p}>0$ represents the organic market reservation price and $\alpha\in[0,1]$ is the substitution degree between goods. It is important to underline that if the goods are independent (no substitution), while if $\alpha=1$, the goods are homogeneous (perfect substitution). The following proposition and corollary hold.

**Proposition 1** Let

$$\tilde{x} = \frac{(\bar{p}-\phi)e_g}{[\phi-(1-\alpha)\bar{p}]n} \tag{3}$$

with $\tilde{x}>0$. If $x<\tilde{x}$ then the optimal quantity chosen by PGS firms is:

$$q_g^\star = \frac{\phi + (e_c + (1-\alpha)(1-x)n)q_c^\star}{e_g + (1-\alpha)xn} \tag{4}$$

while the optimal quantity chosen by TPC firms is

$$q_c^\star = \frac{\bar{p} - \phi - \dfrac{\alpha xn\phi}{e_g + (1-\alpha)xn}}{e_c + (1-x)n + \dfrac{(e_c + (1-\alpha)(1-x)n)\alpha xn}{e_g + (1-\alpha)xn}} \tag{5}$$

Otherwise, if $x\geq\tilde{x}$, then the optimal quantity chosen by PGS firms is:

[1] To learn more on replicator dynamics as well as other selection mechanisms, see, among others, Hofbauer and Sigmund (2003).

[2] Differently, a vertical differentiated market supposes that one good is perceived with higher quality by consumers (see, for further details, the seminal work by Jaskold Gabszewicz and Thisse, 1979).

[3] It is not assumed a different reservation price between goods.

$$\hat{q}_g = \frac{\overline{p}}{e_g + xn} \tag{6}$$

while the optimal quantity chosen by TPC firms is:

$$\hat{q}_c = 0 \tag{7}$$

**Proof**. Given the value of variable $x$, the quantities $q_g$ and $q_c$ are chosen according the first order conditions:

$$\frac{\partial \pi_g}{\partial q_g} = p_g - e_g q_g = 0 \tag{8}$$

$$\frac{\partial \pi_c}{\partial q_c} = p_c - e_c q_c - \phi = 0 \tag{9}$$

From (8) and (9) it derives:

$$p_g - e_g q_g = p_c - e_c q_c - \phi$$

and therefore

$$q_g = \frac{\phi + (e_c + (1-\alpha)(1-x)n)q_c}{e_g + (1-\alpha)xn}$$

that is always positive. Substituting (2) and $q_g$ in (9), we obtain:

$$\overline{p} - \phi - \frac{\alpha x n \phi}{e_g + (1-\alpha)xn} =$$

$$= \left(e_c + (1-x)n + \frac{(e_c + (1-\alpha)(1-x)n)\alpha x n}{e_g + (1-\alpha)xn}\right) q_c$$

Solving with respect to $q_c$, we get:

$$q_c = \frac{\overline{p} - \phi - \frac{\alpha x n \phi}{e_g + (1-\alpha)xn}}{e_c + (1-x)n + \frac{(e_c + (1-\alpha)(1-x)n)\alpha x n}{e_g + (1-\alpha)xn}}$$

which is positive if:

$$x < \tilde{x} := \frac{(\overline{p} - \phi)e_g}{[\phi - (1-\alpha)\overline{p}]n} \tag{10}$$

Conversely, if $x \geq \tilde{x}$, then

$$\hat{q}_c = 0$$

and, consequently

$$\hat{q}_g = \frac{\overline{p}}{e_g + xn}$$

**Corollary 2**. Assuming $\phi > (1-\alpha)\overline{p}$, then $\tilde{x} > 0$ always. However, $\tilde{x} < 1$ if and only if:

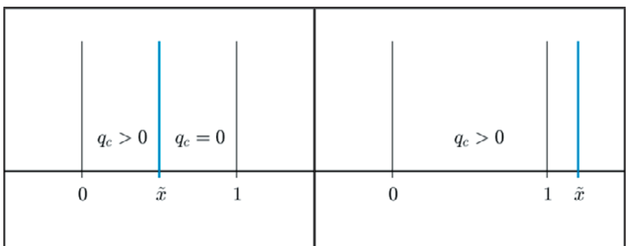
$$\phi > \frac{[e_g + (1-\alpha)n]\overline{p}}{n + e_g}$$

From Proposition 1 it emerges that $q_g > 0$ always, while $q_c > 0$ only if $x < \tilde{x}$. Therefore, if $\tilde{x} \in [0,1]$, then $q_c > 0$ $\forall x \in [0, \tilde{x})$, and $q_c > 0$ $\forall x \in [\tilde{x}, 1]$. Otherwise, if $\tilde{x} \geq 1$, then $q_c > 0$ $\forall x \in [0,1]$. To clarify this point, see Figure 2a-b.

Moreover, from Corollary 2 it is possible to notice that $\tilde{x} \leq 1$ if the certification cost is sufficiently high. This means that $\phi$ if is relatively low, then $\tilde{x} > 1$ and so $q_c > 0$ in the interval [0,1]. Conversely, if $\phi$ is relatively high, then $\tilde{x} \leq 1$ and so $q_c > 0$ only in the interval $[0, \tilde{x})$. Therefore, it is possible that in the transitional dynamics TPC firms produce zero output. However, at increasing time their number converges to zero, and the market will be composed by only firms that produce a positive amount (namely, PGS type).

## 4. DYNAMICS

Suppose now that a firm can choose to be PGS or TPC. Therefore, we can consider the two different modes as two different strategies. This means that, from now, the share $x$ of PGS firms is not fixed but it can change. To do so, we introduce a differential equation that represents the law of motion of $x$. At each instant of time, firms can revise their strategy and choose to change or to continue with that strategy. This selection process is given by the following replicator dynamics (see, among others, Friedman, 1998; Nowak and Sigmund, 2004; Antoci et al., 2019):




**(a)** When $\tilde{x} \in [0,1]$ | **(b)** When $\tilde{x} \geq 1$

**Figure 2.** TPC firms' quantities intervals.

$$\dot{x} = x \cdot (1 - x) \cdot \left[\pi_g(x) - \pi_c(x)\right] \tag{11}$$

where $\dot{x}$ is the time derivative ($dx/dt$) of the share of PGS firms. The mechanism of the replicator dynamics (11) is the following. If $\pi_g(x)<\pi_c(x)$, then the strategy PGS is dominated by the strategy TPC and so the share of PGS firms decreases, namely $\dot{x}<0$. If $\pi_g(x)>\pi_c(x)$, then the strategy PGS dominates the strategy TPC and so the share of PGS firms increases, namely $\dot{x}>0$. Finally, if $\pi_g(x)=\pi_c(x)$, then there is no dominance of strategies and the share $x$ does not change over time, namely $\dot{x}=0$. Moreover, the dynamics (11) admits three types of stationary states: $x=0$ (all firms adopt strategy TPC, namely only TPC firms exist at the equilibrium, in mathematical terms $\pi_g(x)<\pi_c(x)\forall x\in[0,1]$),$x=1$ (all firms adopt strategy PGS, namely only PGS firms exist at the equilibrium, in mathematical terms $\pi_g(x)>\pi_c(x)\forall x\in[0,1]$),$x=x^*$ (some firms adopt TPC strategy, others PGS one, namely both types of firms coexist at the equilibrium, in mathematical terms $\exists x:\pi_g(x)>\pi_c(x)$).

Considering that $p_g=e_g q_g$ (from condition (8)) and that $p_c=e_c q_c+\phi$ (from condition (9)), in the interval $[0,\dot{x})$ where $q_g>0$ and $q_c>0$, the replicator equation becomes:

$$\dot{x} = x(1-x)\left[\frac{e_g}{2}\left(q_g^\star\right)^2 - \frac{e_c}{2}(q_c^\star)^2\right] \tag{12}$$

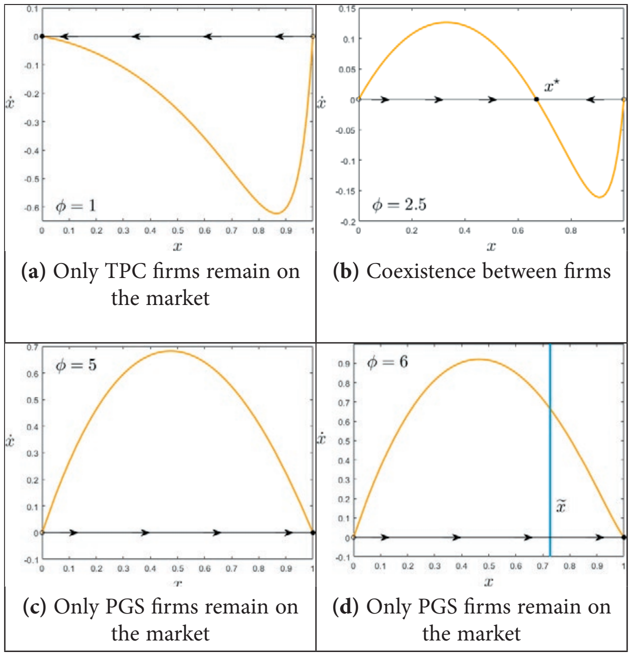
while, in the interval $[\tilde{x},1]$, where $q_g>0$ and $q_c=0$, the replicator equation becomes:

$$\dot{x} = x(1-x)\left[\frac{e_g}{2}\left(\hat{q}_g\right)^2\right] \tag{13}$$

Numerical simulations show that under dynamics (11) three regimes may be observed:

i. the case in which the market is eventually composed of only TPC firms, namely, whatever the initial distribution of modes $x(0)\in(0,1)$, $x$ will always converge to the stationary state $x=0$ (see Fig. 3a);
ii. the case in which both types of firms coexist at the equilibrium, namely, whatever the initial distribution of modes $x(0)\in(0,1)$, $x$ will always converge to the inner stationary state $x=x^*$ (see Fig. 3b);
iii. the case in which the market is eventually composed of only PGS firms, namely, whatever the initial distribution of modes $x(0)\in(0,1)$, $x$ will always converge to the stationary state $x=1$ (see Fig. 3(c) in case of dynamics with $q_c>0$.

In Fig. 3a, Fig. 3b, and Fig. 3c, condition (10) is not satisfied ($\tilde{x}\geq1$), and consequently $q_c>0\forall x\in[0,1]$. A situation in which condition (10) is satisfied ($\tilde{x}<1$) is represented by Fig. 3d, where $q_c>0$ in the interval $[0,\tilde{x})$ and $q_c=0$ in the interval $[\tilde{x},1]$.




**(a)** Only TPC firms remain on the market; **(b)** Coexistence between firms; **(c)** Only PGS firms remain on the market; **(d)** Only PGS firms remain on the market

**Figure 3.** Dynamic regimes. Parameter values: $\alpha=0.95$, $\bar{p}=10$, $e_g=5$, $e_c=5$, $n=5$. Legend: • sinks, ∘ sources.

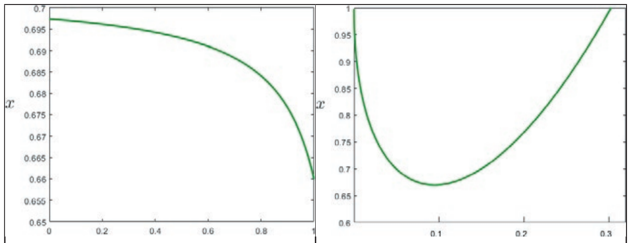
Numerical simulations shown that at most one inner stationary state $x=x^*$ may exist and it is always attractive. The parameters used to perform Fig. 3 have been chosen to illustrate clearly the three regimes that may be observed under dynamics (11). In more detail, the parameters α, $\bar{p}$, $e_g$, $e_c$ and $n$ are the same in all diagrams of Fig. 3. The parameter chosen to show the different dynamic regimes is the certification cost. Indeed, if $\phi$ is relatively low, as in Fig. 3a, then the strategy PGS is dominated by the strategy TPC, and, at the end, the market will be composed of only TPC firms. If the certification cost $\phi$ assumes an intermediate value, as in Fig. 3b, then no strategies dominate, and, since $x^*$ is attractive, at the end, the market will be composed of both types of firms. Finally, if $\phi$ is relatively high, as in Fig. 3c and Fig. 3d, then the strategy PGS dominates the strategy TPC, and, at the end, the market will be composed of only PGS firms.

## 5. SIMULATIONS AND DISCUSSION

In the present section, it has been performed a numerical simulation to analyse the evolution of the share $x$ of PGS firms that occurs when varying some key parameter values, namely, the substitution degree between PGS and TPC goods $\alpha$, the certification cost $\phi$, and the production costs ratio $e_c/e_g$. The parameters underlying the simulations are the same as in Fig. 3b, namely, the case in which both types of firms coexist. The simulations results have to be evaluated in qualitative terms. Indeed, the focus of the present research is on the relations between parameters and market composition. For a quantitative interpretation of the results, the parameter values should have been estimated, nevertheless, this is out of the scope of the paper.

Fig. 4a shows how the share of PGS firms monotonically decreases at increasing values of the substitution degree between goods $\alpha$. The share $x$ reaches its maximum value when $\alpha$=0, namely when there is no substitution between goods (and the output prices, $p_g$ and $p_c$, are independent). Conversely, the share $x$ reaches its minimum value when $\alpha$=0, in case of full substitution (and the output prices, $p_g$ and $p_c$, are the same). Therefore, as $\alpha \to 1$, PGS firms change their strategy adopting the TPC one. This means that the more the PGS product is differentiated, the more it will survive within the organic market. Besides, a rise in $\alpha$ initially causes a slow decrease of $x$, while at higher values of $\alpha$ produces a rapid decrease of $x$. This means that initially (when the goods are enough differentiated) only few firms change their mode to become TPC, while for higher values of $\alpha$ (when the goods tend to be homogeneous) many firms change their mode and become TPC. The model suggests therefore that PGS firms have to differentiate their good to compete with TPC firms. As seen, PGS firms do differentiate their products and they also operate according to a different strategy and philosophy of production by incorporating strong peculiarities of environmental and workers' rights protection as well as elements of social education in relation to quality-of-life improvement. In other words, symbolic attributes such as localness, healthiness, quality, embeddedness among producers and consumers, seem to be able to differentiate PGS products to TPC ones. PGS, indeed, adheres to a model that mirrors the recent critical consumption trends advantaging PGS productions compared to those certified by TPC, accused of being one of the main causes of the conventionalization of the organic model (Raynolds, 2004; Courville, 2006; Hatanaka, 2014).

Finally, Fig. 4b shows the behaviour of $x$ at increasing values of the ratio of the slope of the marginal costs functions $e_c/e_g$. The ratio is always lower than 1 if we assume $e_g \geq e_c$. This ratio can be considered as an increase in the relative marginal costs of the TPC mode compared to the PGS one, or, alternatively, as a decrease in the relative marginal costs of the PGS mode compared to the TPC one. The graph of $x$ in Fig. 4c shows a U-shaped trend. This suggests that a costs saving of the PGS mode compared to the TPC one may initially have adverse effects on the dynamics of the PGS firms. An increase of the production costs ratio has a negative effect on the quantities produced by TPC firms (see (5)) and an ambiguous effect on the quantities produced by PGS firms (see (4)). Clearly, in the early stages, the raise of $e_c/e_g$ has a negative effect on $q_g$ more than on $q_c$ and consequently the PGS mode is less rewarding than the TPC one. However, if then production costs ratio continues to increase, then the positive effect on $q_g$ prevails and so the PGS mode will be more rewarding than the TPC one.




**(a)** Substitution degree. **(b)** Slope of the marginal costs ratio

**Figure 4.** Evolution of the share  of PGS firms at increasing values of $\alpha$, $e_c/e_g$.

According to these results, if the goal of policy-makers is to gradually change unsustainable consumption and production patterns and move towards a better integrated approach of sustainable food systems, they should consider ensuring to PGS firms the access to payments and subsidies supporting and compensating additional costs and income foregone due to the application of environmentally friendly farming practices. Indeed, access to subsides is able to explain Fig 4(b) in the sense that financial support to PGS firms compensate non-financial additional costs linked to their production by lowering and consequently improving the raise of . By financially supporting those farmers, environmentally sound farming techniques could be adapted to region-specific needs meeting the preservation of sustainable production potential according to sustainability criteria. As far as Western countries are concerned, they could also consider the possibility to officially include PGS schemes within organic regulation as to recognize the crucial role played by those operators in the agricultural sector who address a sustainable use of public goods (Schmidt et al., 2012) by adopting environmentally friendly farming techniques that go beyond legal obligations.

## 6. FINAL REMARKS

Worldwide organic standards, certification schemes and regulations ensure organic integrity, but they should do so in a way that does not create unnecessary technical barriers to organic trade, and that respects geographical as well as regional differences. Currently, organic food market has shifted away from its original niche consisting of outlets such as specialized stores, organic farmers markets, direct selling, etc., towards more conventional grocery stores, supermarkets, as well as hypermarkets and even discount stores that have their organic brands. According to previous research, "the globalization of the organic food market could also be associated with the role played by the third-party assurance system" (Sacchi et al., 2015). If on the one hand TPC has produced an increase in trust and reliability in organic goods and their commercialization worldwide, on the other it has meant the occurrence of several problems linked to certification costs as well as difficulties to accomplish all technical and bureaucratic paperwork needed for its request.

In this framework, alternative assurance schemes, known as Participatory Guarantee Systems, have been developed worldwide since the 1980s, originally to assess and guarantee the organic quality of products to consumers, and currently to overcome the barriers posed by TPC. Furthermore, often farmers refer to PGS to differentiate their organic production from those more industrialized traded on mainstream channels. Alternative initiatives suggest that PGS are a valuable tool in differentiating organic productions embracing a philosophy of production that goes beyond the organic production standards and process.

The present research applied the Game Theory approach to develop a mathematical modelling framework able to explain the coexistence of PGS phenomenon within the certification market for organics. From the analysis of the model, it emerges that three dynamic regimes may be observed: (1) an organic market composed of only TPC firms, (2) an organic market composed of only PGS firms, (3) coexistence between firms. Numerical simulations performed in the third scenario, show that by increasing the substitution degree between goods, the share of PGS firms progressively decreases until it reaches 0. This result means that the main way for PGS firms to compete against TPC ones is to differentiate their goods. Numerical simulations also show the possible existence of non-linear effects in response to the change in production costs, so that the share of PGS firms sees an initial (and surprising) decrease before seeing an increase as the TPC mode gets relatively less remunerative.

The present study explicates in mathematical terms the diffusion of PGS behaviour in a population of agricultural firms. On the one hand, the strength of the approach developed is represented by the possibility of presenting in a simple and organized context complex relationship such as those typical of the organic market. On the other hand, one could argue that the present model simplifies the reality by its assumptions. To this purpose, future research could amplify the model by including aspects not considered for analytical simplicity or by modifying some assumptions. For instance, a future line of research could be focused on a model that allows to the same firm to be contextually in a PGS group and certified by TPC, or rather considering a non-competitive but oligopolistic market that could emphasize even more the strategic component of the model. To this respect, our hope is that the present findings will pave the way for more research on PGS certification programs, their strengths and pitfalls, to stimulate a greater debate on both organic producers' and consumers' actual needs. The insights gained from this study, indeed, represent an attempt of indications to policymakers, producers' associations, professionals involved in the sustainability standards discourse, in the improvement of the livelihoods, working conditions, and income of rural populations. From another perspective, the importance of PGS model is also represented by its potential in promoting sustainable consumption by directly involving the participation of consumers. In academic literature there are many examples of consumers concerns about the production, distribution as well as the guarantee processes of agricultural products (Murdoch and Miele, 1999; Murdoch et al., 2000; Caputo et al., 2013; Schnell, 2013; Sacchi, 2018; Kurtsal et al., 2020). Several scholars claim that localness is an attribute often associate to consumer preference and willingness to pay more for local products compared to non-local counterparts (Willis et al., 2013; Carroll et al., 2013; Sanjuán-López and Resano-Ezcaray, 2020). In the same vein, it has also been broadly demonstrated that consumers have a positive WTP for the organic attribute (Loureiro and Hine, 2002; Costanigro et al., 2011; Hu et al., 2011; Zanoli et al., 2013; Gracia et al., 2014; Meas et al., 2014). In this sense, it should be interpreted the advantages of PGS: these systems, in fact, allow for quality assurance for products that conjugate values and attributes of localness and organic production and that can be purchased at a reasonable price. In this sense, policymakers and local authorities should pay attention to these systems that can positively impact both local economies and small farmers' welfare. From a Western perspective, European Union opened a discussion on the possibility of recognizing alternative certification systems to TPC for small farmers. This discussion will lead to the official inclusion within EU countries of the Group Certification as a possible certification strategy within the last Regulation on organic production issued by the Parliament and the Council of the European Union (Reg (EU) 2018/848), that will enter into force on 1st January 2022. At the point (85) the Regulation states that "A system of group certification should be allowed in order to reduce the inspection and certification costs and the associated administrative burdens, strengthen local networks, contribute to better market outlets and ensure a level playing field with operators in third countries". Establishing rules and procedure for implementing group certification could represent a step forward to the recognition of Participatory Guarantee Systems and, eventually, to the access of support payments to small farmers adopting these alternative guarantee strategies.

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