Sustainability of global feeding.Coopetitive interaction among vegan and non-vegan food firms

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June 2018

Sustainability of global feeding.

Coopetitive interaction among vegan and non-vegan food firms

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Abstract

In this paper, we face the problem of global feeding sustainability and related environmental issues, with a strong attention to possible public heath improvements. Specifically, we shall consider food producers and sellers of vegan (or vegetarian) and non-vegan (or non-vegetarian) food. We propose possible quantitative agreements among different food producers, in order to develop a sustainable healthier diet for future generations, by using a mathematical co-opetitive approach and game theory.
The co-opetitive approach used by the authors provides a game theory model, which could help producers of vegan food an easier entry in global market and obtain a considerable free publicity. Meanwhile, the model could allow big producers/sellers of non-vegetarian food a smooth rapid transaction to more sustainable and healthier vegan or vegetarian production/supply. In particular, we propose an exemplary complex agreement setting among McDonald's and Muscle of Wheat, a small but strongly innovative Italian food producer. We think that, on one hand, Muscle of Wheat cannot enter a global market without the help of a large globalized food producer already present in the market, on the other hand, we think equally difficult that a large static and poorly innovative producer cannot follow credibly and rapidly enough the increasing and challenging issues of global food sustainability. We remark that our game model represents an asymmetric R&D alliance between McDonald's and Muscle of Wheat. The aim of our contribution is twofold. Firstly, we explain the advantages of a vegan diet for the human health, environmental issues, food sustainability, population sustainability; in fact, the model explain how global food producers could improve environmental, social and health conditions of world population. Secondly, we show how game theory normal-form and extensive-form games can be used in coopetition studies in order to increase health conditions of people, address climate change, address hunger in the world, improve welfare in a particular market. The results of the mathematical study prove that we can find win-win solutions for both firms, which are also good for world environment, human healthy, human population sustainability and climate change.

Keywords: Sustainability of Food Production, Environmental Sustainability, Game Theory, Co-petitive Games, Green Economy

1. Introduction

In this paper, we study a game theory model in order to improve the sustainability of food production at global level. Specifically, we construct a co-petitive model suggesting general possible alliances among vegan and non-vegan global food producers and sellers.
It is now well known that the meat production is highly non-sustainable, from several points of view (see Leitzmann, 2003, 2014; Fiala, 2008; Worldwatch Institute, 2014; Pimentel and Pimentel, 2003; Wheeler, 2015; Thomas, n.d.; Tuomisto and Teixeira, 2011; Foley et al., 2011; Chu, 2016; Baumert et al., 2005; Nguyen et al., 2012; Gauthier et al., 2016; Lyakhov et al., 2016).
Moreover, the meat consumption reveals linked with heart strokes, cancers, diabetes and several other important diseases (see Saint Louis, 2015; BMJ, 2017; Fields et al., 2016; WHO, 2015; Walker et al., 2005).
On the contrary, a vegan diet is sustainable for the environment, because eating vegan means less impact on the resources of our planet, less energy consumption, less water consumption, less pesticides adoption, less pollutants dispersion, less need for land and therefore less deforestation. Also, a plant-based diet requires only one third of the land needed to support a meat and dairy diet, and is rich in protein, iron, fiber and other essential vitamins and minerals, helping mitigate some of the modern world's biggest health issues like obesity, heart disease, diabetes and cancer. But a vegan diet eliminates food sources of vitamin B12, which is found almost exclusively in animal products, including milk, eggs, and cheese, which are good sources of calcium. To ensure

that “well-planned" diet, vegans must find alternative sources for B12 and calcium, as well as vitamin D, zinc, and riboavin (see Craig, 2009).
We will so analyze the case of the “Muscle of wheat", a food created by Enzo Marascio, an Italian entrepreneur. It is a real evolution in the food industry, because it shows a nutrient value similar to that of meat, while it results totally vegetable. Muscle of wheat results more complete than seitan, soy and tofu; it contains, in fact, 20 amino acids, including the essential 7 amino-acids out of 8, is composed of a type of protein which is not found either in the derivative of soy or in food of animal origins (see Albanesi, 2013).

2. Methods

In this paper we propose the possible agreement among a large globalized food producer and Muscle of Wheat, in order to develop a new better conceived diet for the future generations. We think that Muscle of Wheat cannot enter a global market without the help of a large food producer already in the market, for example like McDonald's or other globalized food chains.
At this aim, we propose a game theory model based on a co-petitive reasoning, representing a possible asymmetric R&D alliance between two subjects: McDonald's and Muscle of Wheat. This asymmetric alliance will benefit different players in the game, Muscle of Wheat will enter a globalized market and export its production worldwide, McDonald's will gain another part of the global food market and society will gain from health improvement.
Although game-theoretical models are not systematically applied in coopetition studies, Game Theory has proved to be extremely useful for coopetition analysis. For example, Brandenburger and Nalebuff (1995, 1996) argued that game theory is useful for understanding co-petitive situations. Rodrigues et al. (2011) applied game theory for investigating strategic coopetition. Moreover, we consider the following literature on asymmetric R&D alliances: Hagedoorn, et al. (2001), Alvarez and Barney (2001).
Here, the authors use an original recent definition of a co-petitive game, in normal form, given by David Carfì. The model can suggest useful solutions to a specific co-petitive problem. This analytical framework enables us to widen the set of possible solutions from purely competitive solutions to co-petitive ones and, moreover, incorporates a solution designed “to share the pie fairly” in a win-win scenario. At the same time, it permits examination of the range of possible economic outcomes along a co-petitive dynamic path. We also propose a rational way of limiting the space within which the co-petitive solutions apply.
The basic original definition we propose and apply for co-petitive games is that introduced by Carfì and Schilirò (2014a, 2012a, 2012b, 2012c, 2012d) and Carfì (2015, 2012, 2009, 2008). The method we use to study the payoff space of a normal-form game is due to Carfì (2015), Carfì and Musolino (2015a, 2015b, 2014a, 2014b, 2013a, 2013b, 2013c, 2012a, 2012b), and Carfì and Schilirò (2014a, 2012a, 2012b, 2012c, 2012d). Other important applications, of the complete examination methodology, are introduced by D. Carfì and co-authors in Agreste et al. (2012), Arthanari et al. (2015), Baglieri et al. (2016, 2012), Campbell and Carfì (2017), Carfì and Donato (2018a, 2018b), Carfì et al. (2017a, 2017b), Carfì, et al. (2017), Carfì, et al. (2016), Carfì and Okura (2014), Carfì and Romeo (2015), Carfì and Pintaudi (2012). A complete treatment of a normal-form game is presented and applied by Carfì (2015, 2012, 2009, 2008), Carfì and Musolino (2015a, 2015b, 2014a, 2014b, 2013a, 2013b, 2013c, 2012a, 2012b), Carfì and Perrone (2013), Carfì and Ricciardello (2013, 2012 a, 2012b, 2010, 2009) and Carfì and Schilirò (2014a, 2012a, 2012b, 2012c, 2012d), Donato (2017). Carfì (2008) proposes a general definition and explains the basic properties of Pareto boundary, which constitutes a fundamental element of the complete analysis of a normal-form game and of a co-petitive interaction.

The economic model

Assumption 1. We assume that, to achieve its goals, *McDonald’s*, our 1st player, is forming horizontal alliances (that is food-food alliances), instead of producing new innovative food, with the small (but research-oriented and highly efficient) *Muscle of wheat* firm, our 2nd player.

Assumption 2. The Muscle of wheat firm (2nd player) is engaged in the creation and production of new vegetable based healthy food, entirely obtained from environmentally sustainable sources. With environmentally sustainable sources, we intend basic primary food products (food raw materials) that:
• do not worsen the natural environment conditions - or, at least, the natural environment used regenerates without human intervention in few months - in which they are produced (on the contrary, e.g. the meat

production requires deforestation and intense use of soil, exploitation of lands, use of pesticides and antibiotics which affect badly on the environment near to the sites of production);
• do not worsen Climate Change, the causes of Climate Change and all the bad effects connected to Climate Change;
• imply less energy consumption, less water consumption, less pesticides adoption, less pollutants dispersion, less need for land and therefore less deforestation, with respect to all other food raw materials (e.g. a plant-based diet requires only one third of the land needed to support a meat and dairy diet);
• reveal essentially healthy, with no particular contraindications or issues for the human health (vegan diet is rich in protein, iron, fiber and other essential vitamins and minerals, helping mitigate some of the modern world's biggest health issues like obesity, heart disease, diabetes and cancer, which follows surely from a high-level consumption of meat and dairy product).

Assumption 3. To cope with global competitive pressures, McDonald's is allying in triad with another mid-size or small-size food firm (our Muscle of wheat) and with a venture capitalist (let us call VC or Cap), our 4th player (which we won't consider one of our principal players, because of its elementary actions and simple payoffs) in order to spin out a new food development program into a new renewable joint venture firm (we call RJV, research joint venture), our 3rd player.

Assumption 4. We assume a particular aggregate demand function describing the demand of the Market:

$$D : E \times C \to \mathbf{R} ,$$

defined by

$$D (x, z) = z_1 + z_2 (1 - x/h_2),$$

for every (x, z) in E x C, where:
• E is a compact interval of the real line;
• C is a compact rectangle of the Cartesian pane;
• h_2 is the maximum of the compact interval C_2, second projection of the rectangle C.

Semi-quantitative description of the payoffs

At the end of this R&D alliance, the benefits for the three partners can be summarized as follows:
• McDonald's buys a certain amount x of food from RJV and gains from the selling of the product

$$\alpha(x, z)\, x$$

on the Market, where

$$\alpha: E \times C \to \mathbf{R}$$

is a percentage function acting on a supply vector

$$(x, z) \text{ in } E \times C,$$

that we specify in the following. The function represents the percentage of production really sold to the Market;
• Muscle of wheat firm produces a bi-quantity

$$z = (z_1, z_2)$$

of a new extremely healthy and highly sustainable food; MW gains by selling a quantity z_1 to RJV and a quantity z_2 on the Market;
• RJV gains by selling x of the Muscle of wheat production to McDonald's and

$$z_1 - x$$

of the food on the Market;
• Cap receives from McDonald's (at time 2) the capitalization k' of its initial investment k (money given to McDonald's at time 1);
• Market gains from the sunk costs k of RJV, from the research-costs y of Muscle of wheat and it gains a value

$$b(z_1 - x + \alpha(x, z)\, x + z_2) = b\, (z_1 - x(1 - \alpha(x, z) + z_2)$$

by improving food production and health.

The formal construction of the game model
Axiom 0. We consider a five-player game.
The players are:
1. The 1st player is McDonald's;
2. The 2nd player is Muscle of Wheat;

3. The 3rd player is the RJV (Research Joint Venture) constituted by McDonald's and MW;
4. The 4th player is VC (venture capitalist);
5. The 5th player, called player 0, is the Market.

We distinguish between principal players and side players: principal players are McDonald's and Muscle of Wheat, side players are RJV, VC and the Market (civil society).

Strategies

Axiom 1 (strategies of the 1st player). Any real number x represents the production that McDonald's decides to buy (x in E, compact interval of the positive real semi-line) from the Research Joint Venture founded by McDonald's and MW.

Axiom 2 (strategies of the 2nd player). Any real number y represents investments for research and food production (y in F, compact interval of the real line, with first end-point greater or equal to 1) employed by MW; we assume that an investment
in research of at least 1 is needed for creating the new extremely healthy and highly sustainable food.

Axiom 3 (co-petitive strategies of the 3rd player). Any vector

$$z = (z_1, z_2),$$

with

$$z \text{ in } C = C_1 \times C_2,$$

where C_1 and C_2 are compact intervals of the real line, such that the first end-point of C_1 results greater or equal to the maximum of E, represents the bi-production of MW.

We assume that:

• the vector z is decided together by McDonald's and MW;
• the RJV buys only the z1 component of z;
• the strategy z_1 could be seen as the strategy of the third player;
• the vector z represents, equivalently, the co-petitive strategy of the first two players.

In other terms, we shall interpret the strategy z_1, first component of the cooperative profile strategy z as the 3rd player strategy.

Axiom 4 (strategies of the 4th player). The number k represents the loan that VC decides to offer to the McDonald's (the strategy set of VC is reduced to the singleton {k}).

Axiom 5 (strategies of the 5th player). Any two-real number $z_1 - x$ and z_2 represents the co-petitive production branded by RJV that the Market decides to buy: we assume, by classic microeconomic assumption, that this $z_1 - x$ and z_2 coincides with the bi-production branded by RJV, decided together by McDonald's and MW.

Axiom 6. We choose the aggregate demand function

$$D: E \times C \to \mathbf{R},$$

defined by

$$D(x, z) = z_1 + z_2 (1 - x/h_2),$$

where h_2 is the maximum of the interval C_2.

Axiom 7 (balance equation of the player 0). The aggregate demand function D must satisfy the following balance equation

$$D(x, z) = (z_1 - x) + z_2 + \alpha(x, z)\, x.$$

We can easily prove the following theorem.

Theorem 1. *The percentage function* α *is defined by*

$$\alpha(x, z) = 1 - z_2/h_2 .$$

Proof. It follows straightforwardly from the definition of α and the definition of D.

From the above theorem we can simplify the notation by considering the function α as a function defined on C_2, in other terms we can consider the function α depending only upon the argument z_2.

Payoffs

Axiom 8. The payoff function of McDonald's is defined by

$$f1(x, y, z_2) = (\alpha(z_2)p_{10} - p_{31})x - k' - ay,$$

where:

1. the term

$$\alpha(z_2)\, p_{10}x$$

is the profit from selling $\alpha(z_2)x$ at price p_{10} in the Market;

2. $\alpha(z_2)$ is a coefficient depending upon z_2, representing the percentage of the quantity x of the product actually sold in the Market by player I, which is defined by

$$\alpha(z_2) = 1 - z_2/h_2,$$

where h_2 is the maximum of the interval $C_2 = [j_2, h_2]$;
3. $p_{31}x$ is the cost to buy x from RJV at price p_{31};
4. k' are the sunk costs faced by McDonald's itself;
5. ay is the extra-payment to MW for research and development y (with a > 1).
Axiom 9. The payoff function of MW is defined by

$$f_2(x, y, z_1, z_2) = p_{23}z_1 + ay - y - F + p_{20} z_2,$$

where:
1. $p_{23}z_1$ is the payment received from RJV selling the product z_1;
2. ay is extra-payment for research y, (with a >1), received from McDonald's; y is the investment in research;
3. F is the fixed cost to produce the food, this cost is not afforded by RJV, which pay only the variable cost;
4. $p_{20} z_2$ is the revenue obtained by selling z_2 in the Market of price p_{20}, with

$$p_{23}<p_{20}<p_{10}.$$

Axiom 10. The payoff function of the RJV is defined by

$$f_3(x, y, z_1, z_2) = p_{31}x + p_{30}(z_1 - x) - cz_1 - p_{23} z_1 - cz_2;$$

where:
1. $p_{31}x$ is the profit from selling x at price p_{31} to McDonald's;
2. the term

$$p_{30} (z_1 - x)$$

is the profit from selling $z_1 - x$ at price

$$p_{30} > p_{31}$$

on the Market;
3. the term

$$c(z_1 + z_2)$$

is the variable cost for the production of $z_1 + z_2$, faced by MW and paid by RJV;
4. $p_{23} z_1$ is the payment paid to MW to buy the product z_1, with

$$p_{30} > c + p_{23}.$$

Axiom 11. The payoff function of VC is defined by

$$f_4(x,y,z) = k' - k$$

where
1. k' represents the money which 1st player has to give back to VC and is

$$k' = k(1 + i)$$

where i represents the interest;
2. k is the number that represents the loan that VC decides to offer to the McDonald's.
Axiom 12. The payoff function of the Market is defined by

$$f_0(x, y, z_1, z_2) = - p_{30} (z_1 - x) + c(z_1 + z_2) + k - \alpha(z_2)p_{10}x + y + b(z_1 - x(1 - \alpha(z_2)) + z_2) - p_{20} z_2$$

where:
1. the term

$$\alpha(z_2) p_{10}x$$

is the cost from buying $\alpha(z_2)x$ at price p_{10} from McDonald's;
2. the term

$$p_{30} (z_1 - x)$$

is the cost from buying $z_1 - x$ at price p_{30} from RJV;
3. the term

$$c(z_1 + z_2)$$

is the indirect gain from the production of z, faced by MW and paid by RJV;
4. y is the indirect gain coming from the research activity of MW;
5. k is the indirect gain coming from the foundation of RJV;
6. the term

$$b(z_1 - x(1 - \alpha(z_2)) + z_2)$$

is the social indirect gain (beneficial effects) coming from the use of the quantity

$$z_1 - x(1 - \alpha(z_2)) + z_2$$

of the new sustainable food.
The following Figure 1 shows the formal situation.

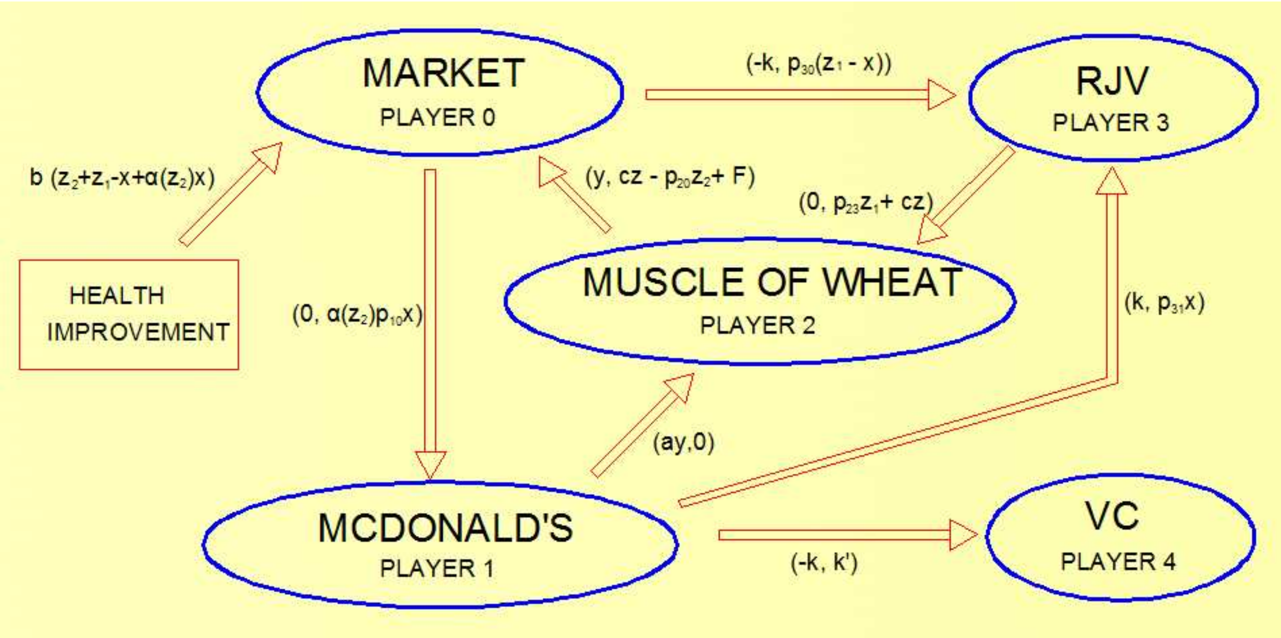

Figure 1. *Formal representation of the game.*

3. Results and Discussion

Numerical sample

Now we propose a numerical sample and then we present possible cooperative and co-petitive solutions. For the complete
game theory analysis and the resolution algorithm we suggest Carfì and Donato (2018b).

We fix the structure constants of the game as follows:

- $p_{10} = 7$ (\$/piece) is the price of the product fixed by all players at which McDonald's sells to the consumers;
- $p_{30} = 7$ (\$/piece) is the price of the product fixed by all players at which RJV sells to the consumers;
- $p_{31} = 1$ (\$/piece) is the price of the product fixed by all players at which RJV sells to the 1st player;
- $p_{23} = 1$ (\$/piece) is the price of the product fixed by all players at which 2nd player sells to RJV;
- $p_{20} = 5$ (\$/piece) is the price of the product fixed by all players at which 2nd player sells to the consumers;
- $k' = 4$ (millions of dollars) represents the capitalized sunk costs paid by the 1st player to the VC (at time 2);
- $a = 1.5$ (pure number, capitalization factor) is extra-payment for a monetary unit employed in the research, paid by
McDonald's to MW;
- $c = 2$ (\$/piece) is the marginal cost of the product- faced by the 2nd player – paid to the Market by the RJV;
- $F = 0.5$ (millions of dollars) is the fixed cost of the production, paid by MW.

We also assume the strategy intervals as:

1. any real number x, that is a possible level of production (in millions of pieces) purchased by 1st player from RJV, in the canonical interval

$$E := [m, n] = [0, 1];$$

2. any real number y, that is an amount of money (in millions of dollars) for research and service production employed by 2nd player, in the interval

$$F := [1, 2];$$

3. any real vector z, that is the total vector production of food (in millions of pieces) decided by both 1st and 2nd players
- of which the part z_1 is sold by the 2nd player to RJV and the part z_2 is sold by the 2nd player to the Market – in the rectangle

$$C = C_1 \times C_2 = [j_1, h_1] \times [j_2, h_2] = [1, 2] \times [0, 2],$$

where we impose $j_1 \geq n$.

We illustrate in Figure 2 the graph of game's bi-strategy space E x F, and in Figure 3, two projections of the 3-strategy space (in particular E × F × C_1 and E × F × C_2); note that our 3-strategy space is a 4-dimensional compact interval.

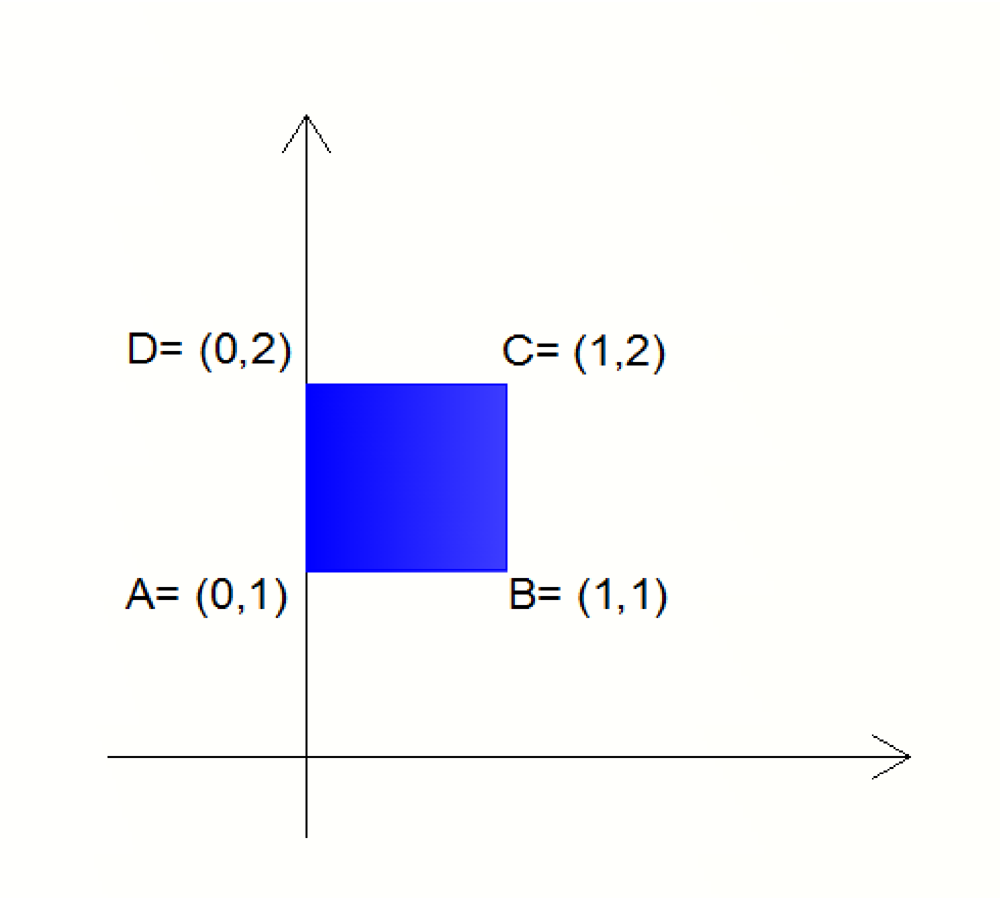

Figure 2. *Bi-strategy space of the game.*

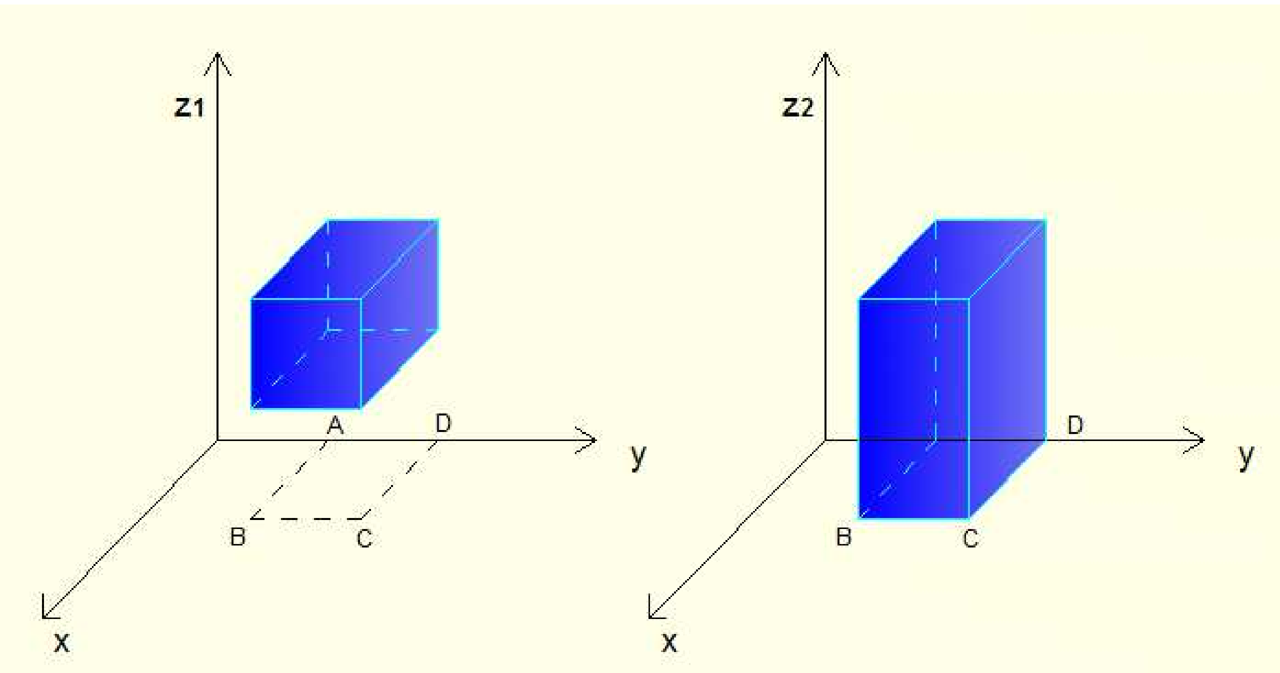

Figure 3. *Two projections of the 3-strategy space of the game.*

We propose two types of solutions.

Purely co-petitive solution

The purely co-petitive solution represents the best Nash equilibrium (payoff) of the co-petitive game, or, more correctly, a compromise solution on the Pareto boundary of the co-petitive Nash zone, that is the dynamic trajectory determined by the Nash equilibria during the co-petitive evolution of the game.

For determining the purely co-petitive solution we first find the Nash equilibria of the game. The Nash equilibria, representing the (static non-co-petitive) competitive solution, are (see also Figure 4):

$$N(z) = \begin{cases} (1,2) = C & \text{if } z_2 < 12/7 \\ [0,1] \times \{2\} = [C, D] & \text{if } z_2 = 12/7 \\ (0,2) = D & \text{if } z_2 > 12/7 \end{cases}$$

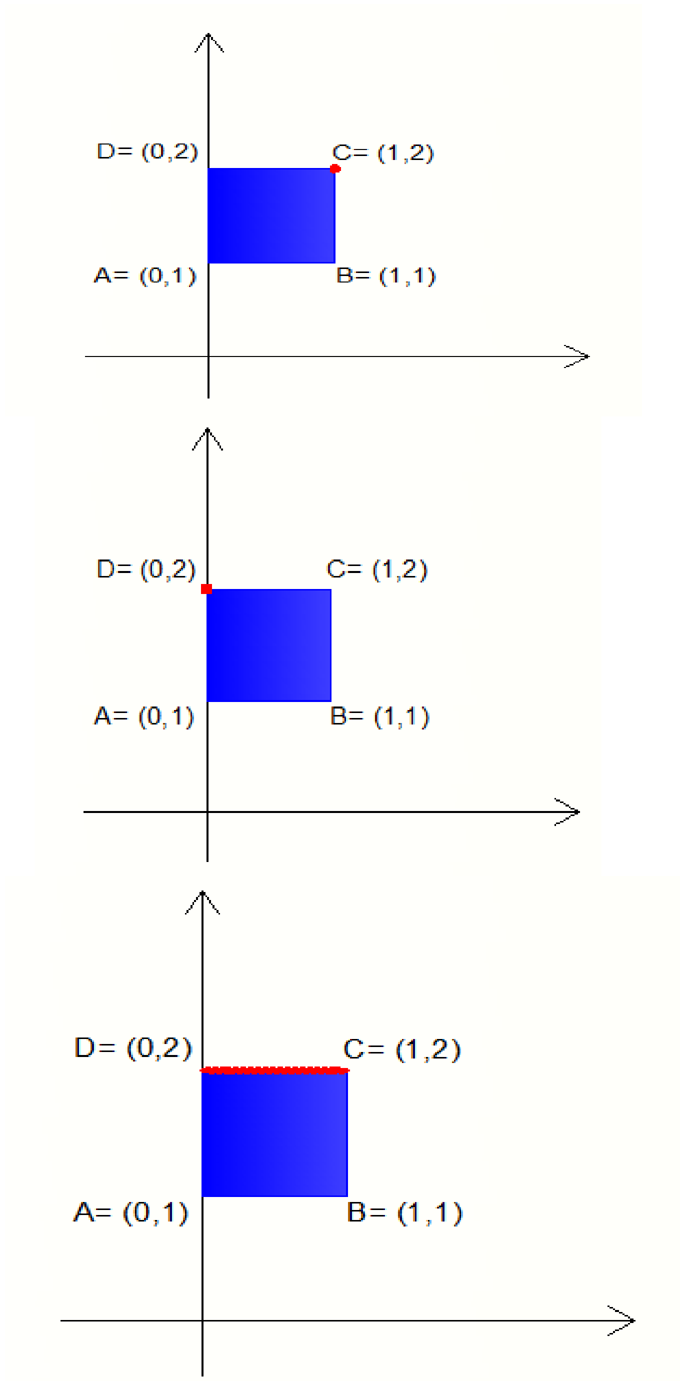

Figure 4. *Nash solution in the strategy space.*

The co-petitive Nash zone, that is the dynamical trajectory determined by the Nash equilibria during the co-petitive evolution of the game, is the convex envelope of the four points

C'(2, 12 /7), C'(1, 12 /7), C'(1, 0), C'(2, 0)

union the segment

[D'(2, 2), C'(2, 12 /7)].

The purely co-petitive solution represents a compromise solution on the Pareto boundary of the co-petitive Nash zone (see Figure 5).

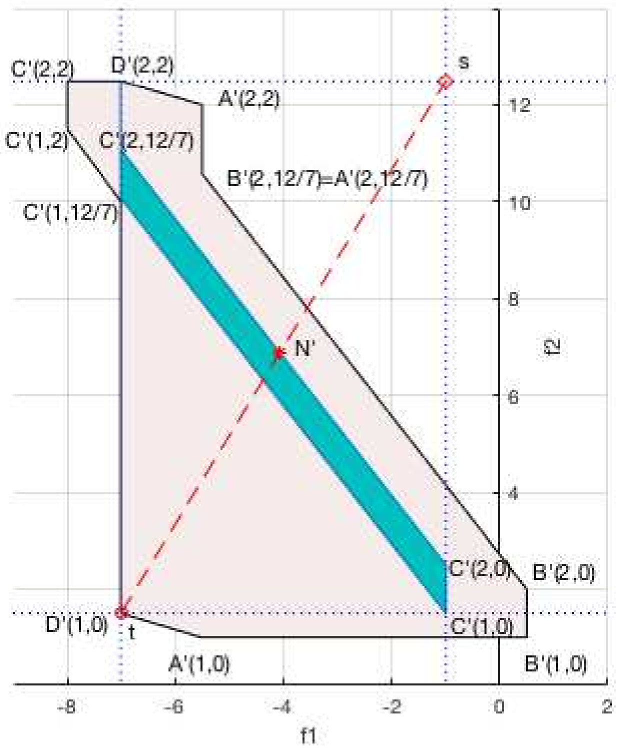

Figure 5. *Purely co-petitive solution of the game*

This point N' is the intersection between the Pareto boundary of the co-petitive Nash zone and the line between the infimum of the Nash zone

t = (-7.5, 1.5)

and the maximum

s = (-1, 12.5).

Note that this purely co-petitive solution does not realize the maximum collective gain.
In the strategy space this solution is represented by the strategy

N = (1, 2, 2, 0.87).

Super-Cooperative solution

The super-cooperative solution represents, in the payoff space, a possible compromise solution on the Pareto boundary of the entire payoff space.
A way to select a solution on the Pareto boundary is to use the Kalai -Smorodinsky method. When we face a bargaining problem (P, t), where P is a Pareto boundary in the Cartesian plane and t is a point of the plane, which is under part of P. The Kalai-Smorodinsky solution of (P, t) is the point (if any) at the intersection between P and the segment [t, s], where s is the least upper bound of the part of Pareto boundary P beyond (greater than) t. Figure 6 shows the solution K'.

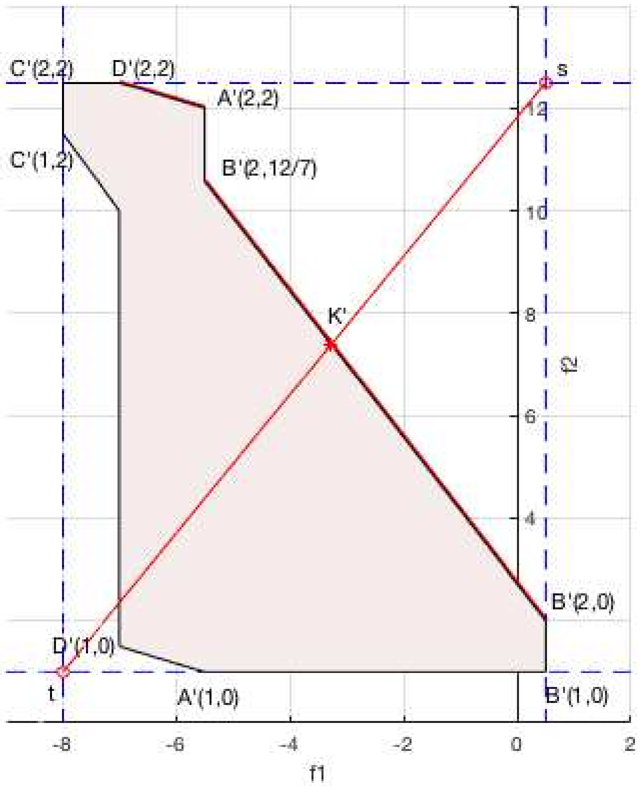

Figure 6. *Kalai solution of the game.*

In the strategy space this solution is represented by the strategy

K = (1, 2, 2, 1.08).

4. Conclusions

In this paper, we propose a possible co-petitive agreement among a large globalized food producer/seller and Muscle of Wheat, a small, local but strongly innovative healthy food producer of southern Italy.

We strongly believe that Muscle of Wheat should enter the globalized market because of the good quality of its food innovation, which is capable to address global issues such as climate change and the current mass extinction, human determined and linked with the extreme soil exploitation; extinction caused also by the requirements of meat industry, for the feeding of animals.

Moreover, McDonald's might see great motivations to change towards the vegan and vegetarian productions, because the world food politics are changing in those directions. In addition, McDonald's, a large, heavy, static and poorly innovative producer cannot follow credibly and rapidly enough the increasing and challenging issues of global food sustainability.

The food production of vegan-products, feasible for the new future feeding scenarios, reveals perfectly matching the Marascio's production of the Muscle of Wheat.

Our aim is to suggest a game theory model based on a co-opetitive reasoning, representing a possible asymmetric R&D alliance between McDonald's and Muscle of Wheat.

The results of the mathematical study have proven that we can find more solutions advantageous both for the firms involved

and for the world environment, the human population sustainability and the climate change.

In particular, in a purely co-petitive fashion, we can suggest the use of the profile strategy (quadruple)

N = (1, 2, 2, 0.87)

which belongs to our strategic space, and, in a super-cooperative scenario, we can suggest the profile strategy

K = (1, 2, 2, 1.08),

which belongs again to our strategic space, where,

the first component of any above quadruple, which belongs to the strategic interval [0,1], represents the production that McDonald’s decides to buy from the Research Joint Venture founded by McDonald’s and MW;
• the second component of any above quadruple, which belongs to the strategic interval [1,2], represents investments for research and food production employed by MW;
• the third component of any above quadruple, which belongs to the strategic interval [1,2], represents the production that RJV decides to buy from MW;
• the fourth component of any above quadruple, which belongs to the strategic interval [0,2], represents the production that MW sells to the consumers.
For example, the first strategy profile means that McDonald's decides to buy exactly a million pieces of innovative new foods from the Research Joint Venture founded by McDonald's and Muscle of Wheat, meanwhile Muscle of Wheat employs $2 million in the investments for research and food production, at the same time the production that RJV decided to buy from MW, reaches 2 million pieces while, the production that Muscle of Wheat sells to the consumers is not the maximum possible production but a percentage indicated by the number 0.87.
From an economic point of view, we are sure that the pure competition is not the right way to gain success, neither at individual level nor to global level.
Food enterprises should decide not to “fight” with other small food companies to grab a good share of the market, but they have to cooperate to reach the maximum collective gain for them and for the social communities. Indeed, it's important, for a world looking to the future, to study what is the best combination of richness for enterprises and welfare for the community and our planet.

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