Coopetitive games and sustainability in project financing

Carfì, David and Patané, Giusy and Pellegrino, Samantha

University of California at Riverside

2011

Coopetitive games and sustainability in Project Financing

David Carfì[1]*, Giusy Patané[2] and Samantha Pellegrino[3]

[1]University of Messina, Faculty of Economics and Department DESMaS, Messina, Italy

[1]University of California at Riverside, Department of Mathematics, Riverside, California, US

*davidcarfi71@yahoo.it

[2,3]University of Messina, Faculty of Economics, Messina, Italy

Abstract. The paper provides a Game Theory model of coopetition which addresses the ***Project Financing problem of supporting the production of energy via sustainable renewable sources***. We mean sustainable energy sources as including all renewable energy sources. In our analysis we consider also the positive impact of technologies that improve energy efficiency. Several solutions of our coopetitive game are considered and determined explicitly.

Keywords. *Sustainability, coopetition, Differentiable Pareto Analysis, microeconomic, Project Financing*

Jel classification. C7, C71, C72, C78, D21.
AMS classification. 91B38, 91Axx. 91A10, 91A12, 91A20 91A40, 91A44, 91A80.

1 Introduction

We consider two banks that may decide to invest in renewable and/or non-renewable energy sources. The first bank can choose any investment x within a certain financial availability range E, for a non-renewable energy of a particular type; analogously, the second bank can choose any possible investments y within a certain financial availability range F, again for the non-renewable energy of the same type. The two banks can offer own financing for the preceding non-renewable sources, because the initial costs for non-renewable energy sources are lower than the initial costs of renewable ones. Therefore, the two banks are competitors in financing the above type of non-renewable energy production. In order to offer an initial financing for a certain renewable energy production, let the initial investment z be quite relevant and assume that the banks cannot grant this financing z independently. On the other hand, the banks should consider not only the initial costs, but also the resource availability and the environmental protection, linked with renewable energy productions - the non-renewable energies don't fulfill these two requirements anyway. Besides, the investment in renewable energy production will be more advantageous in the long run for many reasons:
- constructions will be entrust to technologically advanced leader groups;
- constant index of cover risk;
- legislative context (government incentives);
- low technological risk;
- low market risk (special law favoring the product on the market).

For the above reasons we shall assume that our banks will decide to contribute cooperatively for the financial strategy z. Our model will show how this choice can enlarge the pie of possible gains for the two competitors and how to find a reasonable fair division of the pie and finally, as a side result, to find the optimal compromise between the two alternatives in a coopetitive perspective.

2 A coopetitive model for a sustainable Project Financing

General assumptions. Consider two banks: bank 1 and bank 2; each of them has a payoff function, denoted by f_1 e f_2, respectively. We shall specify soon the domains of these two functions and their quantitative definitions. Each of the two banks practices an own financing activity; we shall indicate the respective sums financed in two analogous non-sustainable energy productions with x and y, and we shall assume these two possible financing belonging to two compact intervals of the real line E and F. The two banks decide (on the other hand) to give a common financial support z to an enterprise producing energy from a sustainable and renewable source. We assume, for sake of simplicity, the common financing z shared equally between them: the partition of z is the pair (0.5z, 0.5z), so that we have the elementary expansion $z = (1/2)z + (1/2)z$.

2.1 Payoff functions

Payoff functions are defined as it follows.

Bank 1. We shall assume the payoff function f_1 of the first bank to be defined on a compact interval E of the real line by the sum of interests of the two financings minus a term depending upon the financial strategy of the other bank 2:

$$f_1 (x, y, z) = x\, i_1 h + (1/2)\, z\, i_3 h - ny,$$

for every x in E, y in F and z in C (the interval of possible common financial strategies). Where:

1) the positive factor $a := i_1 h = a$ is the h-years interest rate corresponding to the positive 1-year interest rate i_1, in simple interest capitalization, that is the interest rate for h years;

2) the positive factor $c := i_3 h$ is the h-years interest rate determined by the 1-year interest rate i_3, relative to the sustainable source energy production;

3) the factor $n > 0$ is an erosion coefficient of the bank 2 versus the bank 1.

From which we have

$$f_1 (x,y,z) = ax + (1/2)\, cz - ny,$$

for every x in E (strategy set of the bank 1), y in F (compact, convex strategy set of bank 2) and z in C (compact, convex common strategy set of the two banks).

Bank 2. Analogously we have

$$f_2 (x, y, z) = y\, i_2 h + (1/2)\, z\, i_3 h - m\, x,$$

where:

1) the positive factor $b := i_2 h$ is the h-interest rate corresponding to the 1-interest rate $i_2 > 0$, in simple capitalization, that is the interest rate for h years;

2) the positive factor $c := i_3h$ is the h-years interest rate determined by the 1-year interest rate i_3, relative to the sustainable source of energy;

3) the positive factor m is an erosion coefficient of the bank 1 versus the bank 2.

From which we have

$$f_2 (x,y,z) = by + (1/2)cz – mx,$$

for every x in E (strategy set of the bank 1), y in F (compact, convex strategy set of bank 2) and z in C (compact, convex common strategy set of the two banks).

2.2 Coopetitive game

Our coopetitive game is the game G = (f, >) with vector payoff function defined by

$$f (x,y,z) = (ax – ny, by – mx) + (1/2) cz (1,1).$$

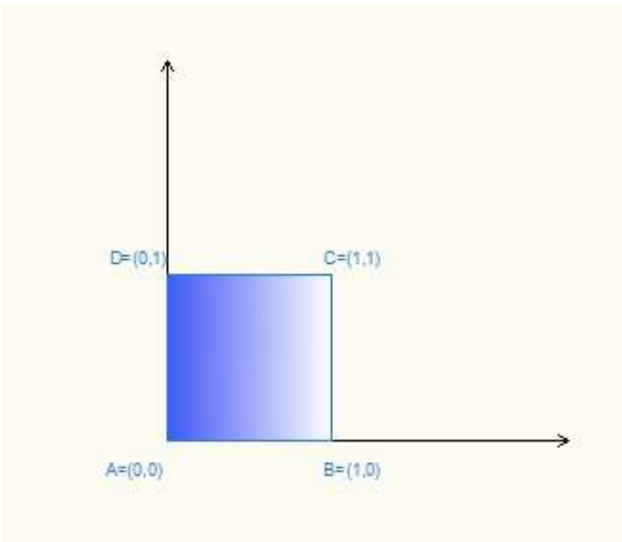
Setting v(z) := (1/2) cz(1,1), for every z in C, we have v(0) = (0,0) and

$$v(2) = (1/2) c (2,2) = (c, c),$$

and the game G(z) is the translation of the initial game G(0) by the vector v(z).

3 Complete study of the coopetitive game

Set of bi-strategies. We shall consider (for simplicity): a = b = 101%, that is $i_1= i_2= 33,\underline{6}\%$, and c = 100%, that is $i_3 = 33,\underline{3}\%$; n = 10% and m = 20%; moreover, x in [0,1], with 1 conventional unit, y in [0,1] and z in [0,2] (all conventional and possibly different unit). So the bi-strategy space is the square with the four vertices: A := (0,0), B := (1,0), C := (1,1) and D := (0,1). The representation of the bistrategy space is the following one:



3.1 Payoff space of the initial game

We have the following transformations:

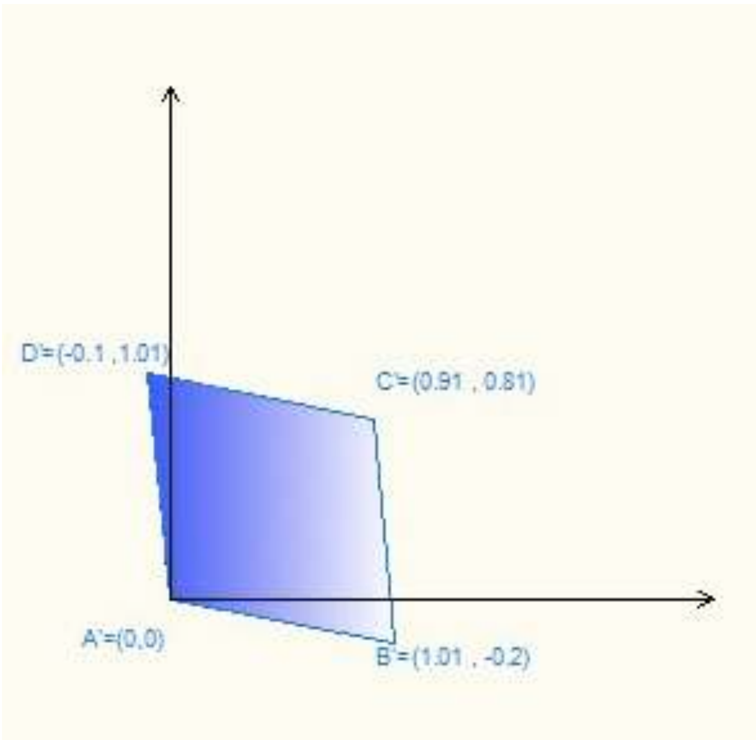
A' := F (A,0) = f (0,0,0) = (0,0);

B' := F (B,0)= f (1,0,0) = (a, -m) = (1.01, -0.2);

C' := F (C,0) = f (1,1,0) = (a-n, b-m) = (0.91, 0.81);

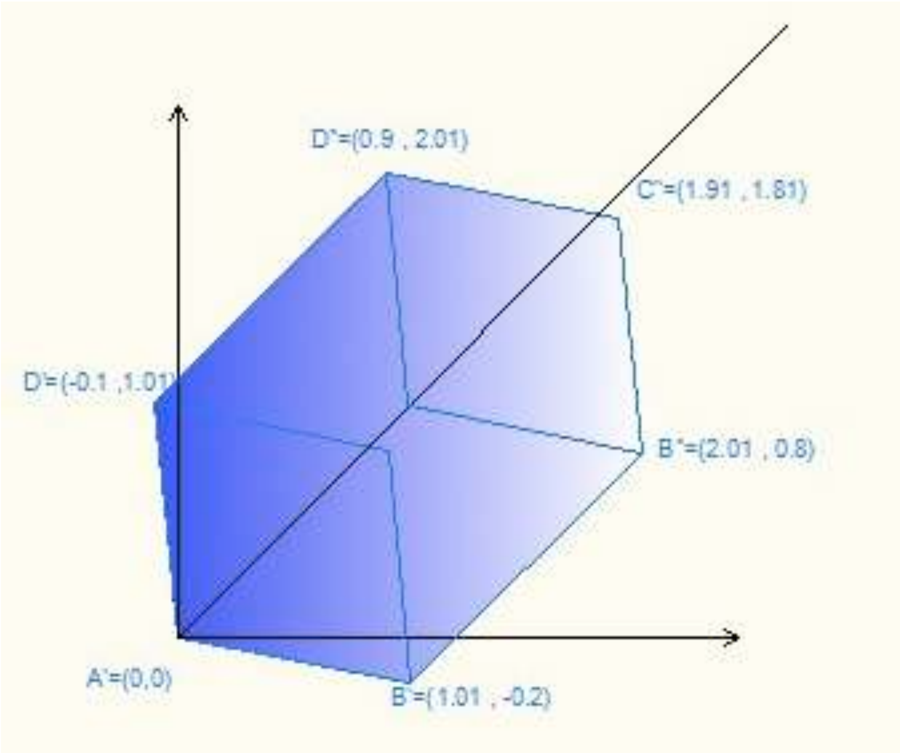
D' := F (D,0) = f (0,1,0) = (-n, b) = (- 0.1, 1.01).

So that we obtain:



3.2 Payoff space and Pareto sup-boundary of the coopetitive game

To the payoff space of initial game G(0) we have to add all possible vectors v(z), with z in the interval [0,2]. We obtain a hexagon with vertices A', B', B'', C'', D'', D', whose Pareto maximal boundary is the bi-segment of vertices D'', C'', B'', as it is shown in the following figure.



3.3 Conservative strategies

Concerning the conservative (or defensive) strategies, we have:

$$v_1^{\#} = sup_{x\in E}\ inf_{y\in F}\ (ax - ny) = sup_{x\in E}\ (ax - n) = a - n = 1.01 - 0.1 = 0.91.$$

So that the conservative strategy of the bank 1 is the strategy 1; moreover we have

$$v_2^{\#} = sup_{y\in F}\ inf_{x\in E}\ (by - mx) = sup_{y\in F}\ (by - m) = b - n = 1.01 - 0.2 = 0.81.$$

Hence also the conservative strategy of the bank 1 is the strategy 1.

The conservative bivalue of the game G(0) is the pair $v^{\#} = (v_1^{\#}, v_2^{\#})$, i.e. the bi-win

C' = (0.91 , 0.81) ,

since this pair C' belongs to the Pareto maximal boundary, the game G(0) is *inessential*. By translation we obtain the conservative bi-value of the game G(z), for every z in C.

3.4 Nash equilibrium

We study the best reply multifunction of Bank 1. We have to find, for every strategy y of Bank 2, the strategies of Bank 1 which maximize the partial gain function $f_1(\cdot, y)$. Since the derivative $f_{1,1}$ (x,y,z) = a is positive, we obtain B_1 (y) = 1, for every y in F. Analogously, the best reply multifunction of Bank 2 - obtained by maximizing the partial function f_2 (x, ·) and considered that the derivative $f_{2,2}$ (x,y,z) = b is positive – is defined by B_2 (x) = 1, for every x in E.

The **unique Nash equilibrium** (of any game G(z)) is the point common to both the best reply graphs: the point C = (1, 1). The Nash equilibrium bi-win of G(0) is the point

C' = (0.91 , 0.81).

Consequently, the conservative bi-value of any G(z) coincides with the payoff of the Nash equilibrium: the point C' + v(z).

4. Coopetitive solutions

At this point we draw in the payoff universe the line of fairness **R**(1,1) and the line of maximum collective gain C' + **R**(-1,1).

1) The equity best compromise solution is the unique point of the Pareto boundary of the payoff space of G belonging to the equity line: the point K'.
2) we can also represent the ***natural competitive solution***: we consider the interval having its inf at the point C' and its sup at the sup of the intersection between the cone of upper bounds of C' itself with the maximum collective gain line: its diagonal C' + **R**(1,1) determines univocally the Pareto payoff C'' .

We have so many possible solutions:

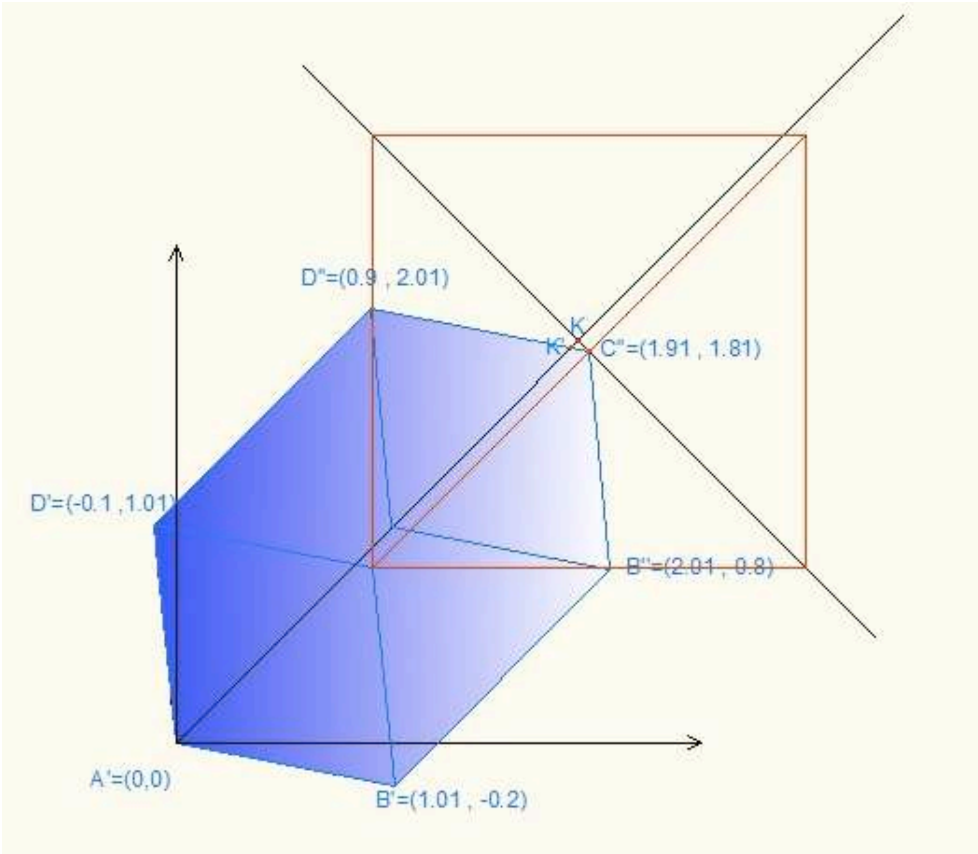
1) K: ***equity transferable utility best compromise*** (maximum collective benefit: intersection of the equity line with the maximum collective gain line);

2) K': ***equity best compromise*** (intersection of the equity line with the Pareto usual boundary);

3) C'': ***properly coopetitive solution*** (Nash equilibrium of the game G(2));

4) C': ***disagreement point of the coopetitive game*** G;

5) K'': ***natural coopetitive solution***, which coincides with C''.



5 Conclusions

Among all, however, the most suitable and reachable payoff solution, for the coopetitive game G, is the bi-gain C'', which:

1) is the properly coopetitive solution;
2) it belongs to the Pareto boundary of the coopetitive game G;
3) it is the natural coopetitive solution when the two banks are cooperating;
4) it belongs to the Transferable Utility Pareto boundary of the coopetitive game G;
5) it is the higher Nash equilibrium of the game G and higher conservative cross.

Strategy solution. The payoff C'' can be reached by proper coopetition: first choosing the cooperative strategy z = 2 and then by competing *a la Nash*.

5 References

Baglieri D., Carfì D., Dagnino G., (2010), “Profiting from Asymmetric R&D Alliances: Coopetitive Games and Firms’ Strategies”, paper presented at the 4th Workshop on Coopetition Strategy “Coopetition and Innovation”, Montpellier, June 17-18, 2010

Brandenburger A.M., Nalebuff B.J., 1995, “The Right Game: Use Game Theory to Shape Strategy”, Harvard Business Review, vol. 64, July-August, pp. 57-71.

Carfì D., 2009, “Payoff space in C1-games”, Applied Sciences (APPS), vol.11, pp. 1-16. http://www.mathem.pub.ro/apps/

Carfì D., 2010, “A Model for Coopetitive Games”, paper presented at Sing6, Palermo, July 6-9 2010

Carfì D., Ricciardello A. 2010, “An Algorithm for Payoff Space in C1-Games”, Atti della Accademia Peloritana dei Pericolanti, Classe di Scienze Fisiche Matematiche e Naturali, Vol. LXXXVIII, n.1, pp. 1-19. http://antonello.unime.it/atti/

Carfì D., Magaudda M., Schilirò D., 2010, Coopetitive Game Solutions for the Eurozone Economy, Quaderno di Economia e Analisi del Territorio, n.55, DESMaS, Università di Messina.

Clarke-Hill C., Li H., Davies B., 2003, “The Paradox of Co-operation and Competition in Startegic Alliances: Towards a Multi-Paradigm Approach”, Management Research News, vol.26, pp.1-20.

Gulati R., Nohria N., Zaheer A., 2000, “Strategic Networks”, Strategic Management Journal, vol. 21, pp.203-215.

Padula G., Dagnino G.B., 2007, “Untangling the Rise of Coopetition”, International Studies of Management and Organization, vol. 37, n. 2, pp. 32-53.

Porter M., 1985, Competitive Advantage. Creating and Sustaining Superior Performance, Free Press, New York.

Schilirò D., 2008, “ Investing in Knowledge: Knowledge, Human Capital and Institutions for the Long Run Growth”, Quaderno CRANEC, Vita e Pensiero, Milano, Novembre, pp.1-31.

Schilirò D., 2009, “Knowledge, Learning, Networks and Performance of Firms in Knowledge-Based Economies”. In New Technologies, Networks and Governance Structures, edited by A. Prinz, A. Steenge, N. Isegrei,, Wirtschaft: Forschung und Wissenschaft Bd. 24, LIT-Verlag, Berlin, pp. 5-30.

Acknowledgments. *Authors whish to thank dr. Eng. Alessia Donato and dr. Giulio Mirabito for their valuable assistance and cooperation.*