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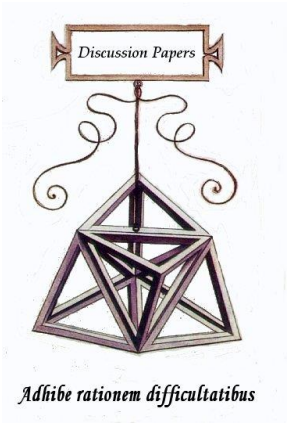

Domenico Buccella - Luciano Fanti - Luca Gori

R&D innovation with socially responsible firms

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Indirizzo degli Autori:

D. Buccella
Department of Economics, Kozminski University, Jagiellońska Street, 57/59 – 03301 – Warsaw, Poland.
e-mail: buccella@kozminski.edu.pl
tel.: + 48 22 51 92 153

L. Fanti
Department of Economics and Management, University of Pisa, Via Cosimo Ridolfi, 10, I–56124 Pisa (PI),
Italy
e-mail: luciano.fanti@unipi.it
tel.: +39 050 22 16 369

L. Gori (corresponding author)
Department of Law, University of Pisa, Via Collegio Ricci, 10, I–56126 Pisa (PI), Italy
e-mail: luca.gori@unipi.it
tel.: +39 050 22 12 847

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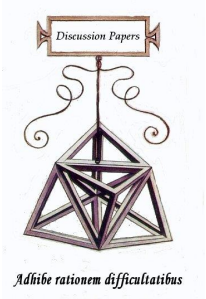

Domenico Buccella -Luciano Fanti -Luca Gori

R&D innovation with socially responsible firms

Abstract

This work revisits the R&D model à la D'Aspremont –Jacquemin (1988) (AJ) in a context with socially responsible firms. In the traditional model firms invest but, in equilibrium, they are cast into a prisoner's dilemma. Socially responsible firms also invest in equilibrium. However, provided that firms consider sufficiently high consumer welfare, to invest is firms' utility-enhancing: the prisoner's dilemma vanishes, and the R&D investment is the firms' Pareto-efficient choice. That is, while in the traditional AJ context to invest in R&D is Pareto-inferior for the whole society, when firms are of CSR type their R&D innovation becomes a Pareto-superior choice.

JEL codes: D43, L13, O31

Keywords: Process innovation; Corporate social reponsibility; Nash equilibrium; Social welfare

R&D innovation with socially responsible firms

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Abstract

This work revisits the R&D model à la D'Aspremont –Jacquemin (1988) (AJ) in a context with socially responsible firms. In the traditional model firms invest but, in equilibrium, they are cast into a prisoner's dilemma. Socially responsible firms also invest in equilibrium. However, provided that firms consider sufficiently high consumer welfare, to invest is firms' utility-enhancing: the prisoner's dilemma vanishes, and the R&D investment is the firms' Pareto-efficient choice. That is, while in the traditional AJ context to invest in R&D is Pareto-inferior for the whole society, when firms are of CSR type their R&D innovation becomes a Pareto-superior choice.

JEL codes: L13, L20, M14.
Keywords: duopoly, CSR, R&D investments.

1. Introduction

In recent decades, the engagement in corporate social responsibility (CSR) activities is a relevant worldwide phenomenon involving several firms. The presence of CSR firms is a dominant global business phenomenon, as the following figures released by KPMG (2020) reveal: 1) while in 1993 only 12 percent of the top 100 companies surveyed in 45 countries have reported the realisation of CSR activities, those figures have increased to 80 percent in 2020 in 52 countries; 2) the 250 Global Fortune Index companies (the world's 250 largest companies) reports that those figures have risen from 35 percent in 1999 to 96 percent in 2020. Furthermore, the European Union institutions believes that it is important to extend the phenomenon of the CSR firms,

D. Buccella (corresponding author)
Department of Economics, Kozminski University, Jagiellońska Street, 57/59 – 03301 – Warsaw, Poland.
e-mail: buccella@kozminski.edu.pl
tel.: + 48 22 51 92 153

L. Fanti
Department of Economics and Management, University of Pisa, Via Cosimo Ridolfi, 10, I–56124 Pisa (PI), Italy
e-mail: luciano.fanti@unipi.it
tel.: +39 050 22 16 369

L. Gori
Department of Law, University of Pisa, Via Collegio Ricci, 10, I–56126 Pisa (PI), Italy, and GLO
e-mail: luca.gori@unipi.it or dr.luca.gori@gmail.com
tel.: +39 050 22 12 847

see e.g. the European Union Commission's Green Paper (2001), ''Promoting a European framework for corporate social responsibility''.

The rationales for a firm to become socially responsible are multiple, and may regard aspects of economics, politics, social integration, and ethics (e.g., Garriga and Melè, 2004). For instance, according to the economists Benabou and the Nobel prize-winner Tirole (2010), CSR is a pro-social behaviour produced by multiple interacting reasons (e.g., pure altruism, material motivation, social and self-esteem concerns). Moreover, looking closer at the economics' approach, the economic aspects of CSR adoption may refer to the so-called stakeholder view of the firm (Freeman 1984): firms' managers aim to satisfy a variety of stakeholders (such as shareholders, consumers, and workers), therefore departing from the standard pure profit maximisation objective.

Likewise, the firms' R&D investments have received an increasing attention in recent years. For instance, the promotion of private firms' R&D investments seems to be crucial for European institution as well. Indeed, the European Commission (2020, pp. 11-13) lists among its current objectives "…strengthening knowledge and innovation as drivers of our future growth…. to re-focus R&D and innovation policy on the challenges facing our society…to prioritise knowledge expenditure….to promote greater private R&D investments".

However, as known from the R&D literature, the R&D investments produce knowledge and information, which have the nature of public goods, and consequently are subject to fundamental market failures. As Poyago-Theotoky (2007, p. 64) clarifies, if there are no leakages of R&D information (or, in other words, spillovers are absent due to an effective patent system), then choosing "their R&D strategically (in the sense that they choose R&D first, followed by output), firms have a tendency to over-invest in R&D as they attempt to gain an advantage over their rivals. This is a strategic over-investment effect". In terms of the pathbreaking d'Aspremont and Jacquemin (1988) model of cost-reducing R&D (AJ henceforth), the over-investment effect results from the Nash equilibrium of the game on the choice whether to invest, which is always a prisoner's dilemma game: firms invest too much in R&D which is detrimental for their profits.

Which are the roles played by the spillover parameter and the cost of R&D on the occurrence of the prisoner's dilemma (e.g., Burr et al. 2013)? First, high spillovers are always expected to reduce firms' incentives for R&D due to the well-known free rider effect of the public goods, and thus also tend to reduce the prisoner's dilemma loss of profitability. Second, higher costs of R&D always reduce the engagement in R&D, and thus indirectly reduce the prisoner's dilemma loss of profitability.

On the other hand, when firms engage in a non-cooperative R&D and are entrapped in a profit-worsening prisoner's dilemma, consumers are better off; moreover, these benefits more than offset the negative impact on firms' profits, and thus social welfare increases. The prisoner's dilemma enhances social welfare as a whole; however, it is Pareto-inferior becauseit benefits consumers but, on the other hand, it hurts firms.

Therefore, the question addressed in this paper relates to the effects of the CSR on R&D investments. In particular, we question whether and how the presence of CSR

affects the unpleasant (for firms) prisoner's dilemma result. To make this point, we extend the AJ model of cost-reducing R&D considering CSR (instead of only profit-maximizing) firms. The rest of the paper is organized as follows. In Section 2, we describe the basic elements of the model. In Section 3, we analyze the welfare properties of the subgame-perfect Nash equilibrium in which both firms invest.In Section 4 we offer some concluding remarks.

2. The model

We assume the following standard linear inverse market demand

$$p = 1 - q_i - q_j \tag{1}$$

where p denotes price and q_i and q_j are the firms' output levels for $i, j = 1, 2$ and $i \neq j$. The following cost function describes the firms' technology:

$$C_i = (w - x_i - \beta_j x_j) q_i ; \; i = 1, 2; \; i \neq j \tag{2}$$

The variables x_i and x_j are the R&D investments chosen by firm i and j, w represents the ex-ante unitary cost of production and, as usual, $\beta_i \in [0,1]$ captures the extent of R&D spillovers. The R&D technology displays decreasing returns to scale, and the cost associated with a reduction of x_i in the unitary cost w is $\frac{\gamma}{2} x^2{}_i$, where γ is a parameter measuring the technology efficiency. Thus profits are

$$\pi_i = (1 - q_i - q_j) q_i - (w - x_i - \beta_j x_j) q_i - \frac{\gamma}{2} x^2{}_i . \tag{3}$$

Following the recent established literature (e.g. Goering 2007, 2008; Kopel and Brandt, 2012; Lambertini and Tampieri, 2012, 2015; Fanti e Buccella, 2017a,b; 2021) this model assumes that all the social concerns can be interpreted as part of consumer surplus: the feature of a CSR firm is to be sensitive to it. Therefore, we suppose that the firm, in its objective, wishes to maximize profits plus the consumer surplus that accrues to its stakeholders. We define the parameter $k_i \geq 0$ as the exogenous weight that each firm puts on the consumer surplus. To simplify as much as possible the analysis, it is assumed: 1) a symmetric weight, k; 2) $\beta_i = 0$, that is, the R&D investment of a firm has no spillover effect on the rival because, for example, R&D results are protected by patents[1]; 3) both the parameters w and γ are adequately high

[1] We observe that, in the context of traditional profit-maximizing firms, the entrapment in the prisoner's dilemma game could be avoided if there exists a high spillover effect (Bacchiega et al., 2010) or product differentiation (Buccella, Fanti e Gori, 2021).

to guarantee that second-order conditions, stability conditions and cost-reducing conditions are all satisfied.
As a consequence, the CSR firm's objective function can be specified as a simple parameterized combination of profits and consumer surplus, which is the firms' utility function (*W*), given by:

$$W_i = \pi_i + kCS = (1 - q_i - q_j)q_i - (w - x_i - \beta_j x_j)q_i - \frac{\gamma}{2}x^2{}_i + k\frac{(q_i + q_j)^2}{2} \qquad (4)$$

We build a three-stage game, whose timing is as follows. At stage 1, every firm's owner decides whether to invest. At stage 2, every firm decides its own R&D expenditure. At stage 3, firms compete in quantities.
This timing implicitly assumes that the decisions of firms about their R&D investments precede those on the quantity. The equilibrium concept considered is the sub-game perfect Nash equilibrium (SPNE) by backward induction.
Hence, the equilibrium of the third stage of the game (the market game) must satisfy:

$$\frac{\partial W_i}{\partial q_i} = 0 \qquad (5)$$

for $i, j = 1, 2$ and $i \neq j$. From (5), we obtain the output reaction functions

$$q_i(q_j, k, x_i) = \frac{1 - w + x_i - q_j(1 - k)}{2 - k} \qquad (6)$$

After the usual calculations, one gets the equilibrium output as a function of the R&D expenditures:

$$q_i(k, x_i, x_j) = \frac{1 - w + 2x_i - x_j - (x_i - x_j)k}{3 - 2k} \qquad (7)$$

By inserting (7) in the objective function (4) (and the same counterparts for *j*), and maximizing the objective function with respect to x_i, we obtain the following reaction functions in the R&D expenditures space

$$x_i(k, x_j) = \frac{4(1 - w - x_j) + 2(1 - w - x_j) + k(5w + 6x_j - 5)}{4(\gamma - 1)k^2 + (11 - 12\gamma)k + 9\gamma - 8} \qquad (8)$$

Solving the system of the reaction functions, one gets the following (symmetric) equilibrium value for *x*

$$x_i = x_j = x^* = \frac{(1 - w)(4 - 5k + 2k^2)}{(4\gamma - 2)k^2 + (5 - 12\gamma)k + 9\gamma - 4} \qquad (9)$$

Lemma 1: i) the output and the R&D investment always increase directly with the level of social concern; ii) the level of social concern always increases output indirectly, via the increase of the R&D investment.
Proof: by inspection of the first derivatives with respect to *k* of (7) and (9) (part *i*), and of the first derivatives with respect to *x* of (7) (part *ii*).

Now, we are in a position to see whether the R&D innovation enhances the utility of the CSR firms. If firms do not invest, their utility is

$$W_i^{NI/NI}(k) = \frac{(1-w)^2}{(3-2k)^2} \tag{10}$$

where the superscript *NI* refers to the case of absence of R&D investment. On the other hand, if firms invest, their utility is

$$W_i^{I/I}(k) = \frac{0.5(1-w)^2\gamma(-4k^4+8\gamma k^2+20k^3-24\gamma k-41k^2+18\gamma+40k-16)}{(4\gamma k^2-12\gamma k-2k^2+9\gamma+5k-4)^2} \tag{11}$$

where the superscript *I* refers to the case of positive R&D investment.

3. The game analysis

It can be shown that the Nash equilibrium of the game, in which every firm decides whether to invest, is that both firms invest[2]. However, we pose the following question: is it really convenient for firms to perform R&D investments? The answer is: it depends on the degree of social responsibility, or in other words, on the consumer surplus' weight in the firm's utility function.
Let us define the following utility function differential between the two cases of investing and not investing:

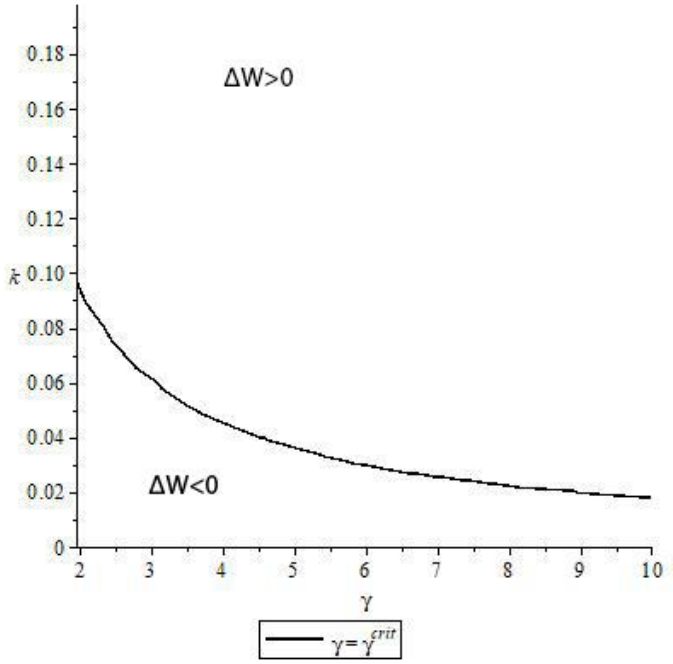
$$\Delta W = W^{I/I} - W^{NI/NI} = \frac{(1-w)^2\gamma(408\gamma k^4+16\gamma k^6-128k^5-650\gamma k^3+8k^4+537\gamma k^2-40k^3-180\gamma k+82k^2-80k+32)}{2(4\gamma k^2-12\gamma k-2k^2+9\gamma+5k-4)^2(3-2k)^2} \tag{12}$$

$$\Delta W \gtrless 0 \quad \Leftrightarrow \gamma \gtrless \gamma^{crit} = \frac{2(4+2k^2-5k)}{k(45+44k^2-8k^3-78k)}. \tag{13}$$

It follows that:

[2] For economy of space, the straightforward proof is available on request.

Figure 1: CSR firms utility differential in the $(g,k)-$ *space.*
For $\Delta W > 0$*, the game is a deadlock; for* $\Delta W < 0$*, the game is a prisoner's dilemma.*



Note: ΔW *in the Figure has been evaluated at* $w = .8$

Result 1. *1) For values of k sufficiently low and* γ *sufficiently high (i.e.* $\gamma \geq \gamma^{Crit}$*) the R&D decision game between CSR firms is of the prisoner's dilemma type, that is, the R&D innovation is detrimental for the firm's utility; 2) For values of k sufficiently high and* γ *sufficiently low (i.e.* $\gamma < \gamma^{Crit}$*) the R&D decision game between CSR firms is of the deadlock type, that is, the R&D innovation enhances the firm's utility.*
Proof: The proof directly derives from Eqs. (12) and (13), where Eq. (13) denotes the critical values of the parameters γ and *k* which are responsible for the *switch* between a prisoner's dilemma game and a deadlock game.

Figure 1 graphically depicts the content of Result 1. When the firms' social concern is not too low, the prisoner's dilemma is eliminated and a win-win outcome emerges, i.e. the SPNE I/I is Pareto-efficient for firms, and then Pareto-superior for the society, because both firms and consumers are better off.
The intuition behind Result 1 is as follows. Lemma 1 reveals that the adoption of CSR behaviours always implies a more intense R&D investments and a larger output. There are, however, two counterbalancing effects of the level of social concern on the utility of the CSR firm. In fact, a larger social concern implies 1) directly, a larger output as well as a larger R&D investment; and 2) indirectly, a further larger output due to the cost reduction induced by the larger R&D innovation. This expansive effect on output leads, on the one hand, to a price reduction which is profit-reducing (in this context, the profit-reducing price effect overweighs the profit-enhancing output effect); on the other hand, to an increase of the consumers' welfare (which

enjoy the results of the lower price and higher quantity). The second effect becomes prevailing when the weight on the consumers' welfare is sufficiently significant.
Needless to say, also workers enjoy the output expansion because employment increases.[3] Hence, the main stakeholders – consumers and workers – enjoy the increase in the firms' social concern, and the corresponding increase in R&D innovation and, ultimately, in output.

3. Conclusions

This paper shows that the adoption of CSR rules always implies a more intense R&D investments and a larger output. If the social concern is low, the R&D innovation reduces the utility of the CSR firm: that is, firms are cast into a classical prisoner's dilemma game. This fact is exacerbated by a low cost of investment, because in such a case firms tend to over-invest. However, if the social concern is not too low, the prisoner's dilemma vanishes and firms increase their utility increasing their R&D innovation. This result arises because in the firm's utility function increases the weight of consumers; thus, the profit-reducing effect is more than counterbalanced by the consumers' welfare enhancing effect. The final result is a win-win effect: the larger the social concern, the larger R&D innovation, and the higher both firms' utility and the utility of the other agents, that is consumers and workers.

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[3] This occurs, for instance, assuming a workers' union interested to the wage bill and then, for a given *w* (interpreted as the wage rate), the employment increase always implies an increase in the utility of the unionised workers. The utility function of the CSR firm does not embed the stakeholder "workers"; however, in the case of its embodying, the paper's results are confirmed *a fortiori*.

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Email della redazione: lfanti@ec.unipi.it