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The Corporate Social Responsibility Is just a Twist in a Möbius Strip

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Abstract
In recent years economic agents and systems have become more and more interactive and juxtaposed, therefore the social sciences need to rely on the studies of physical sciences to analyze this complexity in the relationships. According to this point of view, the authors rely on the geometrical model of the Möbius strip used in electromagnetism, which analyzes the movements of the electrons that produce energy. They use a similar model in a Corporate Social Responsibility (CSR) context to devise a new cost-benefit model in order to take into account three positive effects on the efficiency of a socially responsible company: 1) cooperation among stakeholders in the same sector; 2) cooperation among similar stakeholders in different sectors; and 3) the stakeholders' loyalty toward the company. By applying this model to a firm's decision problem the authors find that investing in CSR activities is always convenient, depending on the number of sectors, the stakeholders' sensitivity to these investments and the decay rate to alienation. Their work suggests a new method of analysis which should be developed not only at a theoretical level, but also at an empirical level.

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Keywords Corporate social responsibility; econophysics; firm behavior

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1 Introduction

In an ever increasing globalized world very complex interactions characterize social and economic relationships. This interdependence both among systems and agents is just the core of the models of Corporate Social Responsibility (CSR), which consider the global integration between firms and stakeholders, including workers, customers and the full environment (Becchetti et al., 2014). CSR implies a move from the maximization of shareholders' wealth to the satisfaction of a more complex objective function in which the interests of all other stakeholders are taken into account. In turn, this also creates benefits for the business. For instance, Becchetti et al. (2014) show that since more and more profit maximizing firms are adopting CSR practices, there must be pecuniary benefits arising from them. The authors also document that CSR has the potential to generate several value-increasing effects by attracting better employees, enhancing their intrinsic motivation and loyalty, reducing staff turnover rates, improving efficiency and by reducing operating costs. In addition, CSR boosts sales revenues, increases rivals' costs and attracts more ethical consumers, so that the firm can benefit from increases in its demand share.

All the above-mentioned advantages can be seen as a type of *ethical capital* accumulated through CSR practices, but they also require the payment of additional costs. By using a dynamic model, Becchetti et al. (2014) underline the conditions implying that such benefits exceed the costs. There is also a broad range of literature on the benefits that, in general, arise by investing in CSR, for stakeholders and in particular for workers. For this reason many analyses use the standard taxonomy of CSR criteria provided by Kinder, Lydenberg and Domini Research and Analytics, Inc. (KLD). They include the following eight wide-ranging categories in the Domini 400 index: i) community; ii) corporate governance; iii) diversity; iv) employee relations; v) environment; vi) human rights; vii) product quality; and viii) controversial business issues. Every category has its strengths and weaknesses identified and analyzed within the index, as well as the suggestion of corporate activities compliant with each specific category. For instance, by using the KLD index, Becchetti et al. (2016) show that CSR firms which take into account workers' well-being are less exposed to business risks and profit volatility. Rob and Zemesky (2002) analyze the effects of the increased productivity of individual workers.

The authors show how specific investiments in CSR can be seen as the optimal incentives that encourage employees to allocate greater effort to cooperative tasks because they derive utility from cooperation. In the meta-analysis devised by Harter et al. (2003), positive workplace, perceptions and feelings are associated with higher business-unit customer loyalty, higher profitability, higher productivity, and lower rates of staff turnover. In Gond et al. (2010) it is explained how employees' perceptions of CSR trigger attitudes and behavior in the workplace, which affect organizational, social and environmental performance. In Degli Antoni and Portale (2011) the empirical relationship between CSR and social capital is analyzed; the authors point out how the adoption of CSR good practices fosters the creation of workers' social capital intended as a cooperative social network, generalized trust, and relational skills. In addition, for an analysis more specifically directed to the benefits of the cooperation between co-workers see Myers and Sadaghiani (2010) who discuss the effects of firm's values and workplace interaction on co-workers. Rast and Tourani (2012) also show, by using the data collected from employees of three private airline companies in Iran, that an important factor that has an impact on job satisfaction and productivity is the relationship with co-workers.

Therefore, according to the CSR point of view, firms and stakeholders can be depicted not as two distinct and unconnected systems but as a crossed-system where transfers occur in such a way that a business becomes part of stakeholders' interest and conversely stakeholders' well-being becomes part of the business. In this crossed-system, the output of each part is transferred across them to become the others' input, so that these subsystems are strongly overloaded and linked inextricably together.

According to this point of view, the best metaphor to approximate and represent this new conceptualization of links in economic systems and between agents is suggested by the physical sciences: it is the *Möbius strip*.

This is a topological enigma independently documented in 1858 by two mathematicians A. F. Möbius and J.B. Listing. It is a bend of paper given a 180 degree twist prior to having its two ends connected.[1]

[1] The first use of the Möbius strip as a metaphor in business relationships, to our knowledge, is that of Litz (2008), who discusses an alternative approach to business family and family business relationships.

In this paper, we explore in more detail what mechanisms are at work to make CSR convenient for a company. For this reason, we draw extensively from the analogies, regarding the behavior of fermions in a Möbius strip, to show the kind of interactions among stakeholders at work. This strongly implies improvements in the company's performance (for a complete survey on the theoretical and empirical works on the forces driving CSR measures and the effects on firms' performance, see Crifo and Forget, 2015). The twist in the Möbius strip generates two important effects on the electrons' trajectories and the energy produced. First, unlike a cylinder, in a Möbius strip an electron moves in a longitudinal direction along the ring, and encircles the system twice before returning to its initial position. This creates flux periodicities, generating a more persistent current. Second, the Möbius strip cannot be pressed into a one-dimensional structure and this implies the motion of electrons in the transverse direction. Therefore, fermions can tunnel to their neighbors in more directions. Finally, thanks to the twist, the electrons in the last wire tunnel in the same wire on the corresponding replicated new element. Then it is possible to notice some very important analogies between fermions moving on a Möbius strip and the effects of CSR investments. In fact, these investments, just like the twist, should make stakeholders' relationships closer and more persistent, so that one stakeholder's interest also becomes an other stakeholder's interest. This is perfectly in agreement with stakeholder theory, which suggests simultaneous attention to the legitimate interests of all appropriate stakeholders, both in the establishment of organizational structures and general policies.[2] In our model, these desired structures and practices are just measured in general by the investments in CSR for workers and sectors, corresponding to

[2] Stakeholder theory was first introduced by Freeman (1984), who argues that a business organization must ensure a minimum benefit to all stakeholders (i.e. not only to its shareholders, but also to its customers, employees, suppliers, and the community with which the organization interacts), which otherwise would leave the company, making it impossible to produce profits. This theory occupies an intermediate position between strategic management and political philosophy in that it presents a new form of sovereignty, i.e. it neutralizes the sovereignty of the firm in favor of the stakeholders (Bonnafous-Boucher and Porcher, 2010) who "are persons or groups with legitimate interests in procedural and/or substantive aspects of corporate activity. Stakeholders are identified by their interests in the corporation, whether the corporation has any corresponding functional interest in them" (Donaldson and Preston, 1995). According to Jensen (2001) "managers should make decisions so as to take into account the interests of all stakeholders in a firm (including not only financial

the energy dissipation for the fermion in a Möbius strip. Nevertheless, these costs represent appropriate incentives for different stakeholders and in different sectors to become strictly interdependent, just like fermions tunneling to their neighbors.

This attention to stakeholders' interests boosts the consequent positive effects on companies' performance due to strong and weak ties characterized by a "combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services. Any given tie may be contagious which enters social networks and is disseminated with increasing rapidity"(Granovetter, 1973). In other words, through investments, the business company creates social capital, functionally defined as "a variety of entities with two elements in common. They all consist of some aspect of social structure, and they facilitate certain actions of actors within the structure, that is, social capital is anything that facilitates individual or collective action, generated by networks of relationships, reciprocity, trust, and social norms" (Coleman, 1988). They may be seen as the incentives that boost prosocial behavior that combines heterogeneity in individual altruism and greed with concerns for social reputation or self-respect, making individuals' actions complementary goods more than substitutes (Bénabou and Tirole, 2006). In our model this prosocial behavior is measured in three crossed effects linking different stakeholders and in different sectors, but also enforcing stakeholders' attraction to the firm's mission, so that each of them can be viewed as replicated, working both for its specific sector and for the firm's mission. Therefore, according to this point of view, it is possible to draw extensively from the topology of the interactions among fermions on a Möbius strip, which is the most appropriate analogy with the interactions among stakeholders in the context of CSR. This is not just an exercise but helps us to devise a new cost-benefit model, as we think those in the traditional economics textbooks are never appropriate for CSR companies. In fact, the traditional models do not take into account the crossed effects and the additional interactions among different stakeholders and different sectors, on which the analogies with fermions shed light.

The paper is divided into four sections (including the introduction and conclusions). In the second section, we describe the building of the geometrical

claimants, but also employees, customers, communities, governmental officials, and under some interpretations the environment, terrorists, and blackmailers)".

model for the electrons travelling in a Möbius strip. In the third section, we investigate how to apply this model to the behavior of firms and economics agents in a CSR context. We devise a new cost-benefit model that shows the convenience of investing in socially responsible activities thanks to three positive crossed effects on the efficiency: 1) cooperation among stakeholders in the same sector; 2) cooperation among similar stakeholders in different sectors; and 3) the stakeholders' loyalty toward the company. We provide an example of a firm's decision problem, which decides whether to invest in social responsibility. Our analytical results show that this is always the optimal choice depending on the number of sectors, the stakeholders' sensitivity to these investments and the decay rate to alienation, which occurs when a worker can only express individuality through a production system, but who derives very little satisfaction from the monotonous activity. Moreover, the alienation of the worker also exists through other workers in a workplace that does not foster social relationships (for a better definition see also https://www.boundless.com/sociology/textbooks/boundless-sociology-textbook/economy-16/work-120/work-and-alienation-678-7760. Our results substantially confirm those of most of the theoretical and empirical literature on the positive effects of CSR on companies' performance (for a survey, see Crifo and Forget, 2015). Nevertheless, referring to the existing literature and in particular to the dynamic model in Becchetti at al. (2014), through the analogies with the Möbius strip it is possible to model what effects are at work to create what those authors called *ethical capital*. In fact, this kind of capital accumulation is only assumed in the theoretical model of Becchetti et al. (2014), and in general in the CSR and stakeholders theory, while a broad range of empirical literature tests the positive effects of several measures of CSR on firms' performance. Our results shed more light on what particular forces are at work, to generate that ethical capital inside the organization. Consequently, they also provide useful suggestions about the variables that should be measured at an empirical level to produce clearer and more appropriate results. In the fourth section, we discuss our conclusions.

2 How to build a geometrical model for the electrons travelling in a Möbius strip

The Möbius strip is a bi-dimensional manifold with only one face. It can be built from a strip of paper by joining together both its ends after having twisted one of them a half turn (see Figure 1).

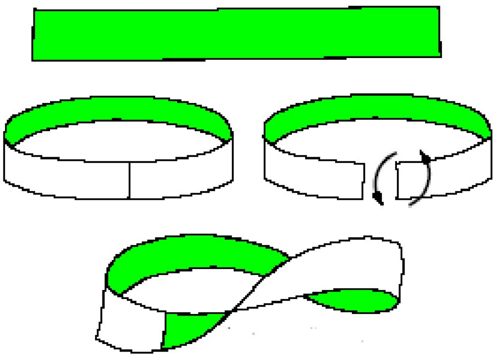

Figure 1: How to build a Möbius strip

The Möbius strip has one side and a single border and if we move along the centre line, the meridian, of the strip we need to go through the circle twice in order to return to the original position. This behavior is similar to that of the electrons generating a flux periodicity of persistent currents in a Möbius strip in Yakubo et al. (2003), who describe it by using the Hubbard model (1963). The latter is the simplest model of interacting particles (electrons) in a lattice and consists of a Hamiltonian with only two terms: a *kinetic term* that represents the kinetic energy of electrons hopping between atoms and a *potential term* consisting of an on-site interaction that represents the potential energy arising from the charges on the electrons. Therefore, the Hamiltonian is the sum of potential and kinetic Energy and is applied to describe how one kind of energy repeatedly changes into the other one over time. If we assume that there are N sites, then we will say that if an electron tunnels from lattice site j to site l, its energy changes by an amount $-t_{jl}$. This tunneling effect is equivalent to annihilating the electron at site j, and creating it again at site l, so the portion of the Hamiltonian, the kinetic term, dealing with tunneling can be written as

$$-\sum_{j,l=1}^{N} t_{jl} a_l^{\dagger} a_j$$

where $a_l^{\dagger}, a_j$ are the fermion (since electrons are fermions), creation and annihilation operators respectively. For many practical purposes it is sufficient to assume that t_{jl} is none-zero, only when j and l are the nearest neighbors, in which case it is usually approximated by a constant t. Because the electron may also tunnel from lattice site l to site j, the Hamiltonian becomes

$$-t \sum_{j,l=1}^{N} a_l^{\dagger} a_j + a_j^{\dagger} a_l$$

where $-t \sum_{j,l=1}^{N} a_j^{\dagger} a_l$ is defined as a Hermitian conjugate and denoted by $h.c.$
The potential term is

$$\sum_{k=1}^{N} \varepsilon_k a_k^{\dagger} a_k$$

where ε_k represents the site energy and $a_k^{\dagger}, a_k$ are the fermion creation and annihilation operators at the site k.
Yakubo et al. (2003) consider electrons moving on a Möbius strip in the longitudinal directions on $2M$ wires and transverse directions on N wires. Specifically, starting from a rectangular lattice including $N \times 2M$ sites (see Figure 2), the rectangle is then twisted by 180 degrees and its two sides are connected, such that longitudinal wire 1 is attached to wire $2M$, wire 2 is attached to wire $2M-1$ and so on (see Figure 3). The Möbius strip so constructed includes M longitudinal wires with $2N$ sites on each one.

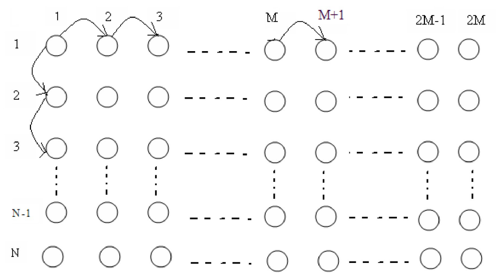

Figure 2: The electrons moving in a lattice $N \times 2M$.

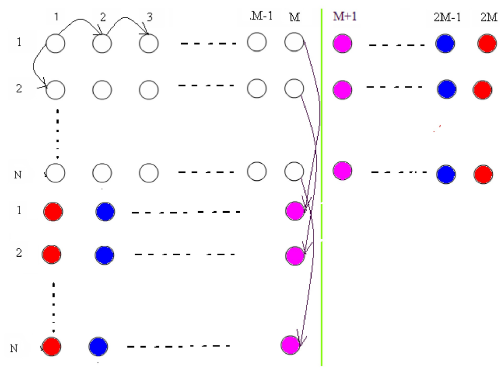

Figure 3: The electrons moving in a Möbius strip.The previous lattice has became a lattice $2N \times M$. The area behind the green line, after the twist, shifted in the bottom on the left. The electrons in the column M that tunneled in the $M+1$ column, now tunnel in the same column M on the corresponding replicated new element.

According to the Hubbard model (1963) the Hamiltonian is then

$$H_{Möbius} = \sum_{n=1}^{2N} \sum_{m=1}^{M} [\varepsilon_{nm} a_{nm}^{\dagger} a_{nm} - t_1 e^{-2i\pi\Phi/N} a_{nm}^{\dagger} a_{n+1m}] \tag{1}$$

$$-t_2 \sum_{n=1}^{2N} \sum_{m=1}^{M-1} a^{\dagger}_{nm+1} a_{nm} - \frac{t_2}{2} \sum_{n=1}^{2N} a^{\dagger}_{nM} a_{n+NM} + h.c.$$

where a_{nm} is the fermion operator at the site (n,m) with $n = 1,2,...,2N$ and $m = 1,2,...,M)$.
The quantity ε_{nm} is the site energy so that

$$\sum_{n=1}^{2N} \sum_{m=1}^{M} \varepsilon_{nm} a^{\dagger}_{nm} a_{nm}$$

represents the potential term.
The kinetic term is made up of three parts:

1. $-t_1 \sum_{n=1}^{2N} \sum_{m=1}^{M} e^{-2i\pi\Phi/N} a^{\dagger}_{nm} a_{n+1m}$ measures the longitudinal hopping, where $e^{-2i\pi\Phi/N}$ measures the effect of the magnetic field accumulated along the longitudinal direction on each link and t_1 is the longitudinal hopping amplitude;

2. $-t_2 \sum_{n=1}^{2N} \sum_{m=1}^{M-1} a^{\dagger}_{nm} a_{nm}$ measures the transverse hopping on $M-1$ longitudinal wires and t_2 is the transverse hopping amplitude;

3. the transverse hopping on the last wire M is measured by $-\frac{t_2}{2} \sum_{n=1}^{2N} a^{\dagger}_{nM} a_{n+NM}$. Without the twist the electron would tunnel from the site (n,M) to the site $(n,M+1)$. But, because of the twist, now the wire $M+1$ is attached to the wire M becoming the same longitudinal wire with $2N$ sites on it. Therefore the site $(n,M+1)$ is now the site $(n+N,M)$ (see Figure 3).Obviously the sum is divided by two because the electrons tunnel only from (toward) the original N sites.

3 The Economics of the CSR-Möbius strip

3.1 How to build a CSR-Möbius strip economics model

In this section, we investigate whether what we have seen in the previous section can be applied to firms and economic agents in a CSR context. Are there some similarities between their activities and contributions to production and the move of electrons in the strip that produces energy? Firstly we notice that $-H_{Möbius}$ strongly approaches a benefit-cost function. In fact, the energy dissipation measured by ε can be assimilated to the production costs unrecovered by selling the added-value of the final consumption good.

Similarly, the terms with t_1 and t_2 may represent the benefits associated with the joint contributions of N stakeholders or type of stakeholders operating in M sectors. For instance in the generalized Leontief production function analyzed in Diewert (1971), the inter-industrial relations of an economy are conventionally represented by a matrix in which each column lists the monetary value of an industry's inputs and each row lists the value of the industry's outputs. Each cell of this matrix might correspond to the site (n,m) of the electrons in the strip (for instance see Iyetomi et al., 2011).

Nevertheless, we think that in the context of CSR this function does not take into account all the crossed effects that socially responsible activities can generate in terms of productivity and costs saving (see Becchetti et al., 2014). In particular, some of these effects concern the externalities due to the CSR benefits for the stakeholders, which in turn are transferred into positive returns within the firm's traditional activities. According to this point of view, we consider a SR company with $n = 1,2,..,N$ stakeholders or cluster of stakeholders and $m = 1,2,...,2M$ activities, where $m = 1,2,...,M$ represents the traditional sectors of production of intermediate goods, necessary to produce the final good M, while $m = M+1,...,2M$ are the specific activities devoted to the CSR. We denote by $0 \leq a_{nm} < 1$ the contribution of the stakeholder n in the sector m measured as a percentage per unit of a product. For instance if $a_{11} = \frac{1}{5}$ we say the stakeholder 1 is able to produce 20 per cent of a unit in a working hour. As in a Möbius strip, also in a socially responsible firm, the effects of a twist may be considered as the returns due to the CSR activities of the stakeholders and firm production, which therefore amplify the

	1	2	...	M	M+1	...	2M
1	a_{11}	a_{12}	....	a_{1M}	a_{1M+1}	....	a_{12M}
2	a_{21}	a_{22}	....	a_{2M}	a_{2M+1}	....	a_{22M}
.	....						
.							
.							
N	a_{N1}	a_{N2}		a_{NM}	a_{NM+1}		a_{N2M}
1	a_{12M}	a_{12M-1}		a_{1M+1}			
2	a_{22M}	a_{22M-1}		a_{2M+1}			
.	....						
.							
.	....						
N	a_{N2M}	a_{N2M-1}		a_{NM+1}			

Figure 4: The matrix of stakeholders'contributions in a CSR context.

crossed contributions of different stakeholders also operating in different sectors of the company (see Figure 4).

The stakeholder 1 contributes with a_{11} to the production of the sector 1 and with a_{12} to the production of the sector 2 and so on. The stakeholder 2 contributes with a_{21} to the production of the sector 1 and with a_{22} to the production of the sector 2 and so on. The same for all the other stakeholders. The value of a_{12M} measures the expected additional contribution that the stakeholders 1 would give, thanks to the socially responsible activity $2M$. The same for the other socially responsible activities, which are ordered in such a way that $2M$ is more relevant for sector 1, $2M-1$ is more relevant for sector 2, etc. (for instance $2M$ could be seen as the socially responsible activities dedicated to assure safe working conditions in sector 1, $2M-1$ those to assure safe working conditions in sector 2 and so on). Therefore, in this work we propose the use of a new cost-benefit function for CSR companies suggested by (1), that in our case becomes:

$$H_{CSR} = -\sum_{n=1}^{2N}\sum_{m=1}^{M}\left[c_{nm} - t_1(1-\delta)a_{nm}a_{n+1m}\right] + t_2\sum_{n=1}^{2N}\sum_{m=1}^{M-1} a_{nm+1}a_{nm} + \frac{t_2}{2}\sum_{n=1}^{2N} a_{nM}a_{n+NM} \tag{2}$$

where

1. $-\sum_{n=1}^{2N}\sum_{m=1}^{M} c_{nm}$ represents the sum of the costs supported by a company for socially responsible activities devoted to each n in the sector m. The company can also decide to give a prize for a stakeholder's socially responsible engagement and his increased productivity in the traditional sectors, so that the cost can be different from zero for the $n = N+1,...,2N$ replicated stakeholders.

2. $t_1\sum_{n=1}^{2N}\sum_{m=1}^{M}(1-\delta)a_{nm}a_{n+1m}$, which we call *the neighborhood efficiency term*, measures the gains associated with the crossed contributions of n in sector m with the nearest $n+1$ in the same sector. For instance if $a_{11} = \frac{1}{5}$ and $a_{21} = \frac{1}{7}$, when the CSR stakeholder 1 supports the stakeholder 2 helping him to produce his share $\frac{1}{7}$, stakeholder 1 contributes with his ability of $\frac{1}{5}$ to the production of $1+\frac{1}{7}$ units of the good. Therefore his total contribution is now $\frac{1}{5}\left(1+\frac{1}{7}\right)$. Obviously the stakeholder 2 can also support the stakeholder 1 and this would correspond to Hermitian conjugate of this term. In the rest of the paper, to avoid excessive complexity, we do not consider the Hermitian conjugate of (2) because this does not affect our analysis. Moreover, we assume that $0 < \delta < 1$ is the decay rate due to the possible effect of alienation (caused for instance by satiety, low free time, etc). Finally t_1 represents the sensitivity of the stakeholders' contributions to the SR activities devoted to them;

3. $t_2\sum_{n=1}^{2N}\sum_{m=1}^{M-1} a_{nm+1}a_{nm}$, which we call *the sector cooperation efficiency term*, measures the gains associated with the crossed contributions of n in the

sector m with the other type of n in the nearest sector $m+1$. Moreover t_2 (which can be equal to or different from t_1) measures the sensitivity of the stakeholders' contributions to the CSR activities devoted to their, and other, near sectors.

4. $\frac{t_2}{2}\sum_{n=1}^{2N} a_{nM}a_{n+NM}$, which we call *loyalty efficiency term*, measures the gains associated with the increased productivity of each n which contributes to the production of the final good M twice: directly through his own task and indirectly through increased efficiency and cooperative attitudes.

Clearly all the above-mentioned crossed effects could run among more distant stakeholders and sectors. Nevertheless, it is reasonable to assume that this would imply not-negligible transaction costs, necessary to raise useful and continuous connections among them. Moreover, the associated benefits should be netted from the intermediate effects running among the nearest ones. Therefore, overall, it is possible to assume, in our model, that those effects are very low and less important for the company when it decides on its investment in CSR.
Moreover, we think that the main point is that SR firms make specific investments (the sectors from $M+1$ to $2M$) to foster stakeholders' socially responsible contributions and productivity (which for examples are empirically measured by an index such as in the KLD metrics, see Becchetti et al., 2016). Therefore, we reverse the upper side of our matrix in the lower bound on the left just as if we have two replicated stakeholders; the traditional one undertaking is own task and the second is a sort of replicated socially responsible stakeholder adding new contributions to the firm.
Therefore, the order matters as investments and returns are specific to the firm. Obviously, we can imagine there are also externalities requiring no specific orders, but they are difficult to measure and not related to specific company's activities and investments, while CSR measures are specific for sectors and stakeholders thus implying specific returns. In particular, the three above-mentioned effects depend on the extremely strict and precise conditions of how CSR investments operate, so that the twist is just a Möbius strip twist rather than some less well-ordered

reshuffling of crosscutting effects across the stakeholders.
In what follows we apply this function to a general decision problem of a company, which wants to minimize its costs, taking into account these crossed benefits due to the SR activities.

3.2 An application to a firm decision problem with constant contributions and costs

In this section we consider only one type of stakeholder and specifically we assume that there are N workers in $m = 1,2,...,M$ traditional sectors. We assume that the total production is equal to the sum of the contributions of these workers, that could be measured in terms of pieces produced by worker in that sector in a working hour, which is constant for each worker and sector, $a_{nm} = a$, with $a \in R$ and $0 \leq a < 1$ for all $n = 1,2,...,N$ and $m = 1,2,...,M$. Therefore, if we denote by p the price of the final good and by w the wages paid to workers, the firm's profit function is:

$$\pi = \sum_{n=1}^{N} \sum_{m=1}^{M} (p-w)a_{nm} = NMa(p-w).$$

We also assume that the company finances the socially responsible activities with an expense $c \geq 0$ equal for each sector and worker, proportional to their contributions, that is $c_{nm} = ca$ for all $n = 1,2,...,N$ and $m = 1,2,...,M$. Note that this assumptions of constant expense c is neither trivial nor unrealistic. In fact, if we consider the same type of stakeholder, in order to avoid any discrimination, the firm should invest, for each them, the same amount which is proportional only to the stakeholder's own contribution (meritocracy). Otherwise it might have counterproductive effects (such as envy, frustration due to inequality, etc.) instead of stimulating cooperation and efficiency. In addition we assume that the workers' sensitivities t_1 and t_2 are equal and related to the investment in CSR through the function

$$t_1 = t_2 = k(ca)^{\beta}$$

where k is a positive constant and $\beta \in R$.
Under these assumptions, the company, for given values p and w, wants to maximize the benefits associated with the investment in CSR measured by the function (2) which in this case is

$$H_{CSR}(c) = -\sum_{n=1}^{2N}\sum_{m=1}^{M}[ca - t_1(1-\delta)a^2] + t_2\sum_{n=1}^{2N}\sum_{m=1}^{M-1}a^2 + \frac{t_2}{2}\sum_{n=1}^{2N}a^2 \tag{3}$$

subjected to

$$NMa[(p-w)-c] \geq 0 \tag{4}$$

Obviously the constraint (4) implies that the firm can not expend in CSR more than what it would earn without socially responsible activities.[3]
Simplifying (3) we get

$$H_{CSR}(c) = -ca2NM + 2kc^{\beta}NM(1-\delta)a^{2+\beta} + 2kc^{\beta}N(M-1)a^{2+\beta} \tag{5}$$

$$+kc^{\beta}Na^{4+\beta}$$

Therefore, the company chooses the value of c that solves

$$\frac{dH_{CSR}}{dc} = 0$$

under (4), that is

$$\frac{dH_{CSR}}{dc} = -a2NM + 2\beta kc^{\beta-1}NM(1-\delta)a^{2+\beta} + 2\beta kc^{\beta-1}N(M-1)a^{2+\beta}$$

[3] Obviously several constraints can exist, which are not always binding, and it could be very interesting to develop a more complex analysis taking into account all these possibilities in a future research. Nevertheless, for sake of simplicity, we focus only on the most essential constraint according to the objectives of this paper.

$$+k\beta c^{\beta-1}Na^{4+\beta}=0$$

$$c^{\beta-1}\beta k[2M(1-\delta)a^{1+\beta}+2(M-1)a^{1+\beta}+a^{3+\beta}]=2M.$$

We can distinguish three cases:

1. for $\beta > 1$

$$c_1^*=\sqrt[\beta-1]{\frac{2M}{\beta ka^{1+\beta}[2M(2-\delta)-2+a^2]}}$$

   which is a feasible solution only if $c_1^* < p-w$. We can see that c_1^* increases for high values of δ. In fact, being convenient to enforce workers' sensitivity to SR to earn the high benefits due to $\beta > 1$, the company should invest more c to counteract the negative effect of δ. Instead the optimal c decreases for high values of β because no huge investments are necessary to stimulate workers' sensitivity and the firm can save costs while receiving the same great benefits. Finally, given the budget constraints, if there are many sectors M the company must invest a small amount c for each of them, therefore c decreases for high values of M.

2. for $\beta < 1$

$$c_2^*=\sqrt[1-\beta]{\frac{\beta ka^{1+\beta}[2M(2-\delta)-2+a^2]}{2M}}.$$

   Obviously the above mentioned effects of δ,β and M on the optimal value of c are reversed when the workers have low sensitivity to SR activities.

3. for $\beta = 1$

$$\frac{dH_{CSR}}{dc}=ka^2[2M(2-\delta)-2+a^2]-2M$$

which is constant. Therefore, if

$$ka^2[2M(2-\delta)-2+a^2]-2M>0$$

it is always convenient to invest in CSR and the company chooses the optimal value of c satisfying (4), as it can easily recover the costs from the proportional increase in t for $k \geq 1$. This condition is more probably satisfied for high values of k and a.

Our findings reveal that the convenience of investing in CSR, and therefore taking care of the stakeholders' interests, produces the effects of strong ties among different workers and in different sectors, boosting social capital and their intrinsic motivation both toward others' and the firm's mission. Nevertheless, these effects in turn are mediated by the three following factors: 1) workers' sensitivity; 2) alienation; 3) the number of sectors.

1. Being favorable to CSR influences productivity, wages of efficiency and intrinsic motivation (see Becchetti et al.,2013). In our decision problem we find that, other factors being equal, workers' high sensitivity to CSR practices makes it convenient for the firm to support the related expenses because the workers' productivity increases. Nevertheless, these expenses decrease as the sensitivity rises because the workers' marginal productivity for units of investment is higher, and the firm can obtain the same effort even with lower costs. Clearly this raises the problem of the right incentives so as not to reduce the workers' sensitivity, because as in Bénabou and Tirole (2003) the wrong incentives, such as donors or wages, could produce the counterproductive effect of crowding out the intrinsic motivations, reducing the value of β.

2. The alienation effect, measured by delta, implies an higher workers' aversion to the task and the company or a greater preference for other activities, leisure or family. If the workers show a high sensitivity to CSR, then the company can enhance their motivations through appropriate investments. In this way, the company can balance costs and benefits for the workers to be engaged in those activities. In other words, delta measures the typical effect

of the depreciation rate in dynamic systems. Therefore, as in the traditional models of investment in physical capital, in this case it is also necessary to invest in a more ethical capital to counterbalance the negative effect of the depreciation rate.

3. The number of sectors affects the investments in CSR in two ways. First, given the budget constraint, if there are many sectors the company can invest a limited amount in each of them. Second, the social capital and workers' relationships are better in smaller sized firms (Tamm et al., 2010) so probably fewer additional responsible investments are necessary compared to larger sized firms. According to our results, this is the case when workers' sensitivity is not significantly high. On the other hand, the larger sized firm with many sectors can reduce the expenses for each sector, obtaining the same benefits because no huge investments are necessary to stimulate workers' greater efforts. Clearly as it is now more convenient to invest in CSR, and the budget constraints being equal, smaller sized firms will be in favor of supporting more expenses for each sector instead of the larger firms. Other works on the problem of the mediator effect of firm size on the adoption of CSR measures substantially confirm that there is no clear effect which is in agreement with our results where they strongly depend on β, i.e. on workers' sensitivity. In particular, Udayasanka (2008) argues that in terms of visibility, resource access and operating scale, very small and very large firms are equally motivated to participate in CSR. However, the motivational bases for CSR participation are likely to be different, so that he suggests caution against the broad categorization of firms, without adequate attention to firm's size. Blomback and Wigren (2009) from examples of far-reaching CSR activities in the small business community and local initiatives by large firms, find that the distinctions suggested in the current discourse do not appear in practice. Local embeddedness, corporate governance, and individual motivation are examples of issues that appear to explain a firm's CSR activities and characteristics, regardless of firm size. Other works approach the question from an empirical point of view. For instance, Youna et al. (2015), performing a two-way fixed-effects model in a firm restaurant context, find that firm size moderates the effect of positive CSR

on Corporate Financial Performance (CFP), while it does not moderate the effect of negative CSR on CFP.

4 Conclusions

In the ongoing times characterized by an even more globalized world, the reduction of distances as a result of modern technologies makes people and systems (economic, social, cultural, etc.) strongly interrelated and juxtaposed. Therefore, what happens somewhere influences things happening elsewhere. From a theoretical point of view, in order to study more interacting systems the traditional economic models are also improved relying on the discoveries of the physical sciences to take into account the many crossed effects within agents' actions. In particular, in a CSR context, its related activities generate a form of interlinked effects, which should be adequately analyzed. In this work we extensively draw from physical science and specifically from the geometrical model of the Möbius strip where the electrons move in several directions to produce energy.

Also in a CSR context, the socially responsible activities have the effect of going in several directions, which can increase stakeholders' productivity and efficiency and so reduce production costs. Therefore, we have devised a new cost-benefit model where three crossed effects are at work: 1) increases in efficiency by virtue of the augmented cooperation among the nearest stakeholders in the same sector; 2) increases in efficiency by virtue of the augmented cooperation among stakeholders in the nearest sectors; 3) increases in efficiency due to the augmented stakeholders' loyalty toward the vision of the company (and also the management and the shareholders) and thus toward its final production.

We show how the benefits of CSR, thanks to those three effects, may incentive of the investment in CSR activities and we also provide an example of how this new cost-function can be used to analyze a simple SR firm's decision problem. Our results show that investing in CSR activities can always be convenient, depending on the number of sectors, the stakeholders' sensitivity to these investments and the decay rate to alienation.

We think that this approach could shed light on the effects on productivity which have not been adequately taken into account and need to be analyzed more, both at a theoretical and empirical level. In particular, proceeding from our theoretical model, new empirical measures on these crossed effects should be produced to translate our model into reality.

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