Article

A sustainability analysis of environmental management approaches: Prevention, mitigation and compensation

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Abstract
The scientific literature has taken Environmental Impact Assessment (EIA) as a promoter of sustainable development only in a normative way, hampering the comprehension of the instrument's potentialities and weaknesses. Therefore, it is necessary to insert the debate about EIA effectiveness in a framework that conceptualizes sustainability more clearly. This framework can be raised by economic theory, which is based on the capitals substitution approach. The present paper analyzes how EIA's main forms of environmental impact treatment can induce sustainability in the relationship between productive processes and environmental systems, taking into account capitals substitution ideas. The paper is based on an analysis model built in systemic precepts. It was possible to observe that economic projects' environmental aspects can be classified into four major groups concerning capital substitution: extraction, edification, creation of cultivated natural capital and injection of energy/matter into the environment. It was also observable that EIA's preventive means avoid capitals substitution and induce strong sustainability, whilst mitigation means avoiding capitals substitution only partially, which makes less effective in inducing sustainability and, finally, compensation means legitimate capitals substitution, inducing weak sustainability. The most effective forms of environmental impact treatment are those less applied in the brazilian context, meanwhile the less effective are those mostly applied. In this sense, the EIA practice in Brazil does not induce economic productive processes to the path of global environmental system's sustainability.

Keywords impact assessment; ecological economics; environmental management; environmental planning.

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1 Introduction

Environmental Impact Assessment (EIA) is one of the most popular environmental policy instruments. It is responsible for significant advances in the strengthening of environmental issues worldwide and is also recognized as a key tool to guide the relationship between society and environment through the path of sustainable development (Caldwell, 1998; Petts, 1999; Glasson et al., 2005; Sánchez, 2006).This relation is set in EIA principles: “ensuring next generation’s well-being” (Glasson et al., 2005), but it has been treated without theoretical approach by EIA guidelines.

EIA aims to regulate some economic agents’ by their “projects” - in this case, engineering projects. Glasson et al. (2005) consider “project” and “development action” as synonyms. These projects can be individuals or institutions, public or private.

There are some “sustainable approaches” derived from EIA and from Strategic Environmental Assessment (SEA), sometimes called “integrated assessment”, which incorporated social and economic considerations, beyond environmental ones (Pope et al., 2004). In Brazil, EIA includes the environmental, social and economic considerations and can be considered as an instrument to improve sustainable development in planning and management of projects.

Pope et al. (2004, page 598) assert that sustainability (or sustainable development) is “a difficulty concept to define in a way that is meaningful and sufficiently practical to allow it to be operationalised”. Just as these authors, this article does not distinguish the concepts of sustainability and sustainable development.

Kates et al. (2005) highlight those thousands of institutions include sustainable development in their goals and/or use it to guide the formulation of plans, programs and assessment methods. To Sneddon (2000), the term ‘sustainable development’ has an ambiguous theoretical basis and does not consider adequately the structural forces behind environmental issues, a matter that may result in catastrophic consequences in ecological terms. The author asserts that sustainability has a defined conceptual basis that allows researchers to examine specific human projects, such as hydropower plants, highways and resorts.

This paper evokes the need to go beyond the established relation between EIA and normative notions of sustainable development. As presented by Pope et al. (2004), Hacking and Guthrie (2008) and Bond et al. (2012), there are several versions about sustainability assessments, some of them based on "three pillars approach", such as Devuyst (1999) and Gibson (2006).

It is surely important to advance in terms of integrating development dimensions and these papers undoubtedly address such an issue. However, we regard that the integration of normative guidelines, objectives and concepts will produce a still normative solution. Thus, we consider that the relationship between EIA and sustainability must be too understood based on scientific foundations that give it theoretical consistence in order to enhance the instrument's effectiveness. Amongst the wide variety of approaches to the sustainability issue, we choose economics’ as theoretical basis.

Attached or not with sustainability concept, according to Petts (1999), the literature about EIA is wide and dominated by a discussion of methodological aspects to operationalised its aims. However, the understanding about the potential and limits of this operationalisation is still a lack in EIA literature.

The planning, implementation and operation of projects can decrease the environmental quality and EIA must reduce this effect. For this, EIA have to put in the gap between projects and environmental quality. In this gap there are a set of elements called “environmental aspects”, which are inseparable of productive process and can interact with the environment, changing its quality (Sánchez, 2006). So, environmental aspects are the last causal nexus between project and environmental impact (Fig. 1).

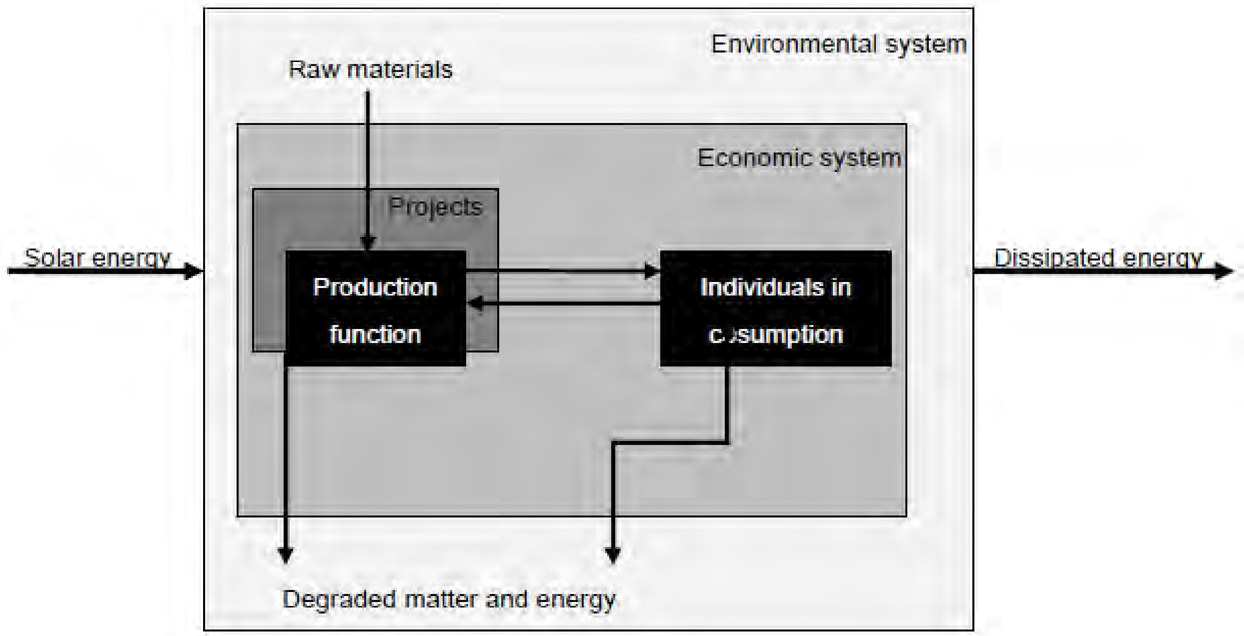

Fig. 1 Analytic model: interactions between economic and environmental systems.

The suppression of vegetation to build a highway or to form a dam reservoir is an example of environmental aspect. Achieving a project implies, necessarily, achieving all its environmental aspects. Achieving EIA to manage the environmental impacts implies, necessarily, managing the environmental aspects.

Overall, the impact management is set up by three kinds of actions which manage the environmental aspects: prevention, mitigation and compensation. This article discusses how prevention, mitigation and compensation can improve sustainable development, enhancing the comprehension of EIA's by environmental economics approach. Therefore, the analytical framework of this paper is based on a discussion about the productive process and the substitution between natural and man-made capitals.

This approach considers that productive process is based on a complex interaction between economic and environmental systems, considering that economic system is totally inserted in the environmental system (Fig. 1). The terms "economic system" and "environmental system" are analytical categories traditionally used by environmental economics literature, such as Costanza (1991), Costanza (1994), Geldrop and Withagen (2000), Daly and Farley (2004), Common and Stagl (2005), Mueller (2007) and Cavalcanti (2010).

Then, if EIA aim to regulate some parts of the productive process, it is important to understand how this process works. Therefore, the next topic shows the importance of the productive process to the understanding of the sustainability issue and the regulation role that EIA can play.

2 A Short Review of the Productive Process

Pearce and Turner (1990) consider the maintenance of a sustainable economy depends on two factors: (a) the technological progress in order to increase efficiency in the use and exploitation of natural resources; and (b) the substitution of natural capital by man-made capital.

According to Pearce and Turner (1990), sustainability promoted by a human action can be theoretically interpreted based on its results in the maintenance or substitution of natural capital by man-made capital. These authors classified human actions into two groups: weak sustainability inducers and strong sustainability inducers. First one is based on neoclassical environmental economics and the second is based on ecological economics.

The neoclassical conception recognizes the importance of bio-physical elements based on natural resources stocks and deposits for waste. For this conception, the limits imposed by the environment can be overcome by technological progress.

Ecological economics assumes that the economy is an open system inserted in the biosphere, interacting by matter and energy flows with bio-physical elements. Furthermore, economy operates under thermodynamic laws and economic activity is not considered perpetual and self-sustained (Constanza, 1991; Common and Stagl, 2005; Mueller, 2007; Cechin, 2010).

Overall, the main difference between these streams is that the elasticity of environmental limits is close to 100% according neoclassical conception, whereas this elasticity is lower for ecological economics.

So, the human actions, and their environmental aspects, can improve strong sustainability when they are planned to run according the bio-physical limits. Otherwise, they improve weak sustainability based on the idea that these limits can be largely changed by technological issues.

Knowing each stream's conception of the productive process is indispensable to understand the logical construction behind those divergent points of view. They will be briefly in turn.

2.1The neoclassical conception of the productive process

The neoclassical environmental economics stream conceives utility aspect in the same way that neoclassical economics does. Orthodox economic theory manuals provide a generic conception of the utility process, representing it as a "cake recipe kind" production function (as wrote Mueller, 2007, page 188). The neoclassical conception is adopted by the economic science's mainstream. According to Mueller (2007) and Cechin (2010), it is generally determined by

$$P = A\ .f\ \{W,H,N\}$$

where P= the amount of products

W = the amount of work

H = the amount of human capital

N = the amount of natural resources

A = the available productive technology which can improve production efficiency

Variables W, H and Nare considered process' inputs

This approach is based on neoclassical macroeconomic production function, which is defined as income as a function of capital and labor. This production function has been modified by the work of Robert Solow and Joseph Stiglitz to take account of natural resources as a source of income generation. Thus, the Solow-Stiglitz variant incorporates natural resources in its new formulation

$$Y = Kt^{\alpha}.Lt^{\beta}.\ R^{\gamma}.T^{t}$$

where Y= the production

K = the produced capital

L = the labor force

R = the natural resources

T = the technological level

$\alpha.\beta.\ \gamma.t$ represents the elasticity of output with respect to capital, labor, resources and time

This expression shows theoretically that there is substitutability between produced capital and natural resources, and only depends on the elasticity between them. Furthermore, it indicates that the natural system (resources and ecosystem services) couldn´t be a restriction on the indefinite expansion of the economic system (Thirwall, 1999; Romeiro, 2003).

When neoclassical theory assumes that all productive factors have the same importance, it creates the opportunity of facing them as equivalent, that is, one is highly substitutable by another. According this, the results is important and each input can be substituted by another (Geldrop and Withagen, 2000; Mueller, 2007; Cechin, 2010).

However, the neoclassical environmental stream considers that production factors are not completely substitutable by each other, asserting that, in some cases,it is apparently impossible to substitute 100% a factor by another. Even so, this stream believes in a general rule in which the substitutability degree is generally close to 100% (Mueller, 2007).

In this sense, variables *W*, *H* and *N* of equation (1) would have a high elasticity of substitution. Therefore, a variable could fulfil another one's role in the function. It means that *N* could have its contribution diminished whilst the contribution of *W* and/or *H* grows.

Natural resources would be potentially substitutable by other factors, especially man-made capital (variable *H*). According to neoclassical environmental economists, the accomplishment of such a substitution would not bring any negative implications to utility performance. It would persist like it has always done normally. Natural resources would have the same importance as any other factor (Mueller, 2007; Cechin, 2010).

From this reasoning emerges the neoclassical environmental economists' notion on sustainability, consolidated by Solow (1974). Solow's formulations use microeconomic assumptions of high capital substitutability and take them to the macroeconomic level. Solow asserts that natural resources have a relatively small importance in the economic system's operation and expansion and are almost absolutely substitutable by products, such as buildings, power plants, machinery and labour etc., in an economic view.

Capitals are the basic elements of economic activity and their accumulation is the driving force of the economic system's development. Based on Prugh et al. (1999), Common and Stagl (2005) and Mueller (2007), the capitals are classified according to what they represent within an economic activity:

- Stock of machinery, buildings and other physical equipment and tools generated and accumulated by the economic activity, called man-made capital (Km);
- Stock of labouring abilities, called human capital (Kh);
- Stock of institutions under which the economic activity organizes itself, called social capital (Ks); and
- Stock of natural resources available for use by mankind, called natural capital (Kn).

For Solow (1974), the real meaning of sustainability is not to compromise the next generations' welfare when trying to reach the present generation's maximum welfare. According to him, it would be unfair to increase infinitely the actual standard of living at the expense of future generations' welfare.

So, the utility generated by the economic activity has to be sustained as a legacy to future generations, assuming that it is the factor that brings individuals' welfare. This means that the total utility produced by the economic activity should rise.

Solow (1974) asserts that what must be assured over generations is the capacity of *per capita* consumption, which should never decrease. Otherwise, the increase of *utility* is compromised and the future generations would be severely injured by the lack of opportunity to enjoy the same welfare as the present generation does (Turner, 1997; Mueller, 2007; Cavalcanti, 2010; Cechin, 2010).

In this context, the substitution of Kn by Km would be facilitated by technical progress. For neoclassical environmental stream, technological innovations are naturally guided by the goal of making humanity less and less dependent on natural resources, diminishing their intensive use. This would occur in two ways: the first, in which new technologies would enable the production of a product unity using lower and lower amounts of natural capital, and the second, in which innovations would raise the elasticity of substitution between Kn and Km (Costanza, 1994; Turner, 1997; Common and Stagl, 2005; Mueller, 2007).

The neoclassical framework was defined by Pearce and Turner (1990) as the “weak sustainability hypothesis”. Counter pointing the neoclassical point of view, ecological economics conceives productive process, capital substitution and the sustainability issue in a different way.

2.2The ecological economics conception of the productive process

The ecological economics conception of productive process is originated from the writings of Nicholas Georgescu-Roegen, who inspired ecological economics conception of productive process (Gowdy, 1994; Mueller, 2007; Cechin 2010).

The first big difference between the neoclassical conception and Gerogescu-Roegen’s is that, to him, production factors are classified into two groups: stock factors and flow factors. Stock factors would be the material base on which the process occurs and would provide services in input conversion to products. The stock factor does not physically incorporate in final products, as its purpose in productive process is functional and not material. Georgescu-Roegen divides stock factors into three categories: ricardian land (L), man-made or produced capital (tools, equipment, buildings; E) and labour force (F). Ricardian land is a reference of model proposed by David Ricardo, whereby the population growth increases the demand of food, which leads the agriculture expansion to less fertile lands, which increases the food prices, which increases the number of paid workers, which decreases the gain of landowners, increasing gains for the owners that have better lands (Buchholz, 2000, p.96). So, ricardian land can be understood by natural resources whose scarcity influences economy.

Flow factors are elements changed during a productive process, being someway incorporated in the final products. They carry matter or energy through the process and are also classified into three groups: nature inputs (R); produced current inputs from another productive process, like steel and wooden boards (I); and maintenance necessary for the good operation of machinery, like parts and oil (M).

Therefore, stock factors would provide services in the flow factors’ transformation, and the production function would be:

$$Q(t) = f\{L(t), E(t), F(t), R(t), I(t), M(t), D(t)\}, \text{ with } t \text{ between } \{0, T\},$$

where L = the ricardian land
E = the man-made capital in physical infra-structure form
F = the amount of labour force
R = the amount of nature inputs
M = the stock factors’ maintenance coefficient
t = the time over which a certain factor is used
Q = the amount of products generated
D = the amount of wastes generated by the process

The stock factor’s participation initiates at moment zero (t=0) and stops at moment T. Georgescu-Roegen stressed that stock factors must leave the process in the same state they entered. However, as the author asserts that it is impossible as all factors degrade during the productive process, a phenomenon explained by the second law of thermodynamics, he considered M responsible for the stock factors’ integrity.

Another difference between Georgescu-Roegen's and the neoclassical conceptions concerns the productive process' outcomes. While the neoclassical stream advocates that a productive process generates only the desired product, Georgescu-Roegen considers that it consists of a material and energetic transformation, which necessarily results in another outcome: low quality waste.

Ecological economics criticizes the superficiality of the neoclassical framework, believing that the neoclassical notion of equivalence among all production factors is quite limited, far from reflecting the real productive process behaviour (Cechin, 2010).

For ecological economics, each production factor has particular importance in the productive process achievement, and the absence of any factor can surely harm the economic activity. The elasticity of substitution between factors might exist, but in a much lower degree than the neoclassical approach.

As Prugh et al. (1999) assert, for Georgescu-Roegen followers, production factors are much more complementary than substitutes.

In this sense, ecological economics theoretical formulations are distinct from the neoclassical point of view. Under the same logic about productive process' factors, ecological economics separates each type of capital (man-made, human social and natural) into two components: stock and flow.

So, according to ecological economics, man-made capital (Km) can be dismembered into its stock component (Kms, which represents machinery, buildings and further tools) and flow component (Kmf, which represents materials already transformed by man that will be converted into products by stock capitals, such as steel).

According to Mueller (2007), some types of Kms can be replaced by other stock services, like labour force and ricardian land. However, as England (2000) asserts, Kms and Kmf would be complementary and not substitutable for each other.

Natural capital (Kn) would also be dismembered into stock component (Kns) and flow component (Knf). Knf would represent those natural resources that enter the productive process and are transformed by it, such as wood, coal and bauxite. They are typically classified into renewable and non-renewable, but this issue will not be aimed at by this article.

Kns would represent the "ecosystem services". From this point of view, natural capital would provide services not only to economic activity, but also to the maintenance of physical-biotic conditions that make persistence of life on Earth. Those services participate in the productive process as stock factors, and are indispensable to its accomplishment.

Based on the ecological economics conception of economic activity, the equation that represents the total capital composition would be

$$K = \{Kms + Kmf\} + \{Kns + Knf\} + Kh + Ks.$$

Following Costanza (1994), Prugh et al. (1999), Common & Stagl (2005), Mueller (2007) and Cechin (2010), this article will focus on man-made and natural capitals, not dealing with human (Kh) and social capital (Ks).

Ecological economics adepts share a crucial hypothesis that has determining implications in this stream's conception of sustainability: it is impossible to substitute some ecosystem services' role in the productive process by any other factor. In other words, ecological economics discards the neoclassical hypothesis that asserts man-made capital as a almost full substitute to natural resources.

Therefore, ecological economists do not agree with Solow's ideas. They believe that natural capital is the only type of indispensable capital because it is involved not only in the economic activity, but also to biosphere maintenance as a whole. This idea is presented in Pearce and Turner (1990), who called it "strong sustainability hypothesis”. It is basically the conception that natural and man-made capitals have a limited elasticity of substitution between each other, and no technological progress can reproduce the biosphere’s vital functions with the same thermodynamic efficiency.

2.3 Capitals substitution and the interaction between systems

Fig. 2 shows the proposed model of economic and environmental systems’ limits (represented by the larger rectangles), the major economic system’s components (smaller rectangles), the stock and flow capitals (circles, each one named according to the component capital denoted by them), the physical flows of energy and matter (full arrows) and the services provided by stock capitals (dotted arrows). Course, in reality, the borderlines between systems are not as clear as in Fig. 2.

Through of Fig. 2, the main input received by the environmental system is solar energy. It triggers environmental processes that generate the flow and stocks of natural capital (Kns and Knf, respectively). The energy from the Sun is degraded within the environmental system and the generated heat is dissipated to the exterior.

The main input – energy and material – received by the economic system comes in flow natural capital form and has a close relation to the stock component of natural capital. The wastes generated by the economic system’s internal processes are its main output and are sent to the environmental system as inputs.

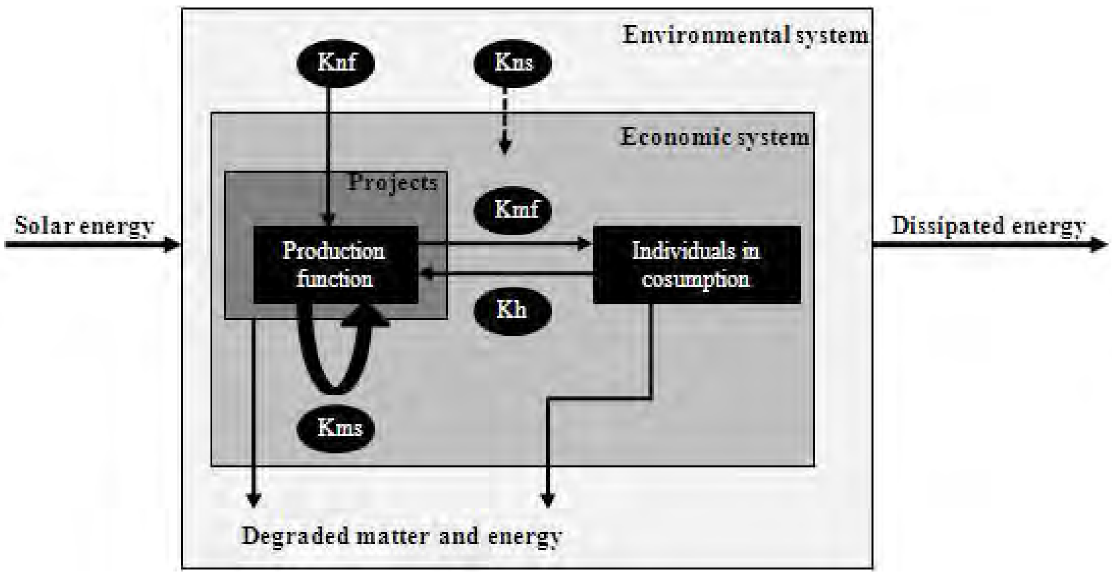

Fig. 2 Interactions between economic system and environmental system.

Already given examples of environmental aspects, such as the pollutant emission of a factory, the removal of vegetation to build a highway and the demand for water or fuel in a beverage industry, illustrate projects' components interacting with the environmental system.

In this sense, the substitution of natural capital by man-made capital can be seen as the core of the concept of environmental aspect. It is even possible to affirm that this capitals substitution is accomplished by the concretization of projects’ environmental aspects. The possibilities of impact management (prevention, mitigation and compensation) to regulate capitals substitution will be discussed next.

3 EIA's Regulation Role

According to Zeiss (1991), there are three different approaches of impact management: prevention, mitigation and compensation. Sánchez (2006) ranks the temporal occurrence of these actions within the EIA process as illustrated in Fig.3. Glasson et al. (2005, p. 152), despite using the term "mitigation" for all mechanisms of impact management, propose a similar hierarchy that "focuses on the principle of prevention rather than cure".
The prevention can occur in the early stages of project’s planning process, when comparative analyses of project alternatives could result in a greater or smaller occurrence of negative impacts or even their total avoidance.

Prevention is normally enforced by the proposition of constructive alternatives for the project, although it is not necessary to adopt the alternative which entails minor negative impacts (Wathern, 1990). Petts (1999), Lawrence (2003), Glasson et al. (2005) and Sánchez (2006) stated that these alternatives can be either technological or locational.

Fig. 3 Mitigation hierarchy forms of impact management by effectiveness and temporal occurrence. Source: adapted from Sánchez (2006).

At planning stages, the mechanism of prevention is: changes of alternatives imply changes of environmental aspects and, therefore, their impacts. Ultimately, this chain of changes can completely avoid the impact. Considering a highway project, an overpass can avoid the vegetation suppress (environmental aspect) and, therefore, can avoid the loss of biodiversity (negative impact).

There is another mechanism of prevention related with risk management: risk control avoids environmental aspects and, therefore, their impacts.

According to Glasson et al. (2005) and Sánchez (2006), some negative impacts are unavoidable by alternative changes. Thus, mitigation aims to reduce the intensity of negative impacts that resulted from alternative choosen. Considering a “ground level” highway as a project and the fragmentation of a high biodiversity area as an environmental aspect, the resulting negative impact can be the geographic insulation of fauna communities. A possible mitigation is a wildlife crossing structure, like a tunnel.

Finally, there are impacts that could be neither prevented nor mitigated. For these, compensatory actions generally seek to create situations in which the foreseen scenario can offset the potential environmental damage, although this equivalence can never be absolute. According to Sánchez (2006), compensating is the act of substituting a good for an equivalent one. Illustrative examples are the creation of protected areas to compensate vegetation suppression and the transfer of money to maintain protected areas.

In summary, prevention is more effective than mitigation, because prevention can avoid negative impact. Mitigation is more effective than compensation, because mitigation can reduce negative impact and compensation can’t. The measure of impact management proposed in Morris and Thérivel (2009) and the "mitigation hierarchy" presented in Glasson et al. (2005) corroborates this statement.

Although prevention is considered the most effective in the impact management, in some cases, it can decrease economic efficiency of project. Considering a highway project, an overpass (technological alternative) can increase projects costs, making it economically unviable. According Sánchez (2006), that is why prevention is underemployed.

However, according Macintosh and Waugh (2014), when there are perfect information and perfect substitutability between productive factors, this mitigation hierarchy makes no sense because we know the optimal mitigation package and there are no substitution problems.

This inference can justify some evidences found in Brazil. MPU (2004) has found that, among the three EIA’s forms of impact management, prevention is the least applied, while compensation is admittedly the most. The study points a wide range of deficiencies in the Brazilian statements, such as absence of alternative propositions, low-quality alternatives (when they are presented) and prevalence of economic criteria in their selection.

Based on the economic theory presented above, how could prevention, mitigation and compensation regulate capitals substitution?

The environmental aspects related to the substitution of Kn by Km concern physical and biotic dimensions. Sánchez (2006) highlights that some aspects affect not only physical and biotic dimensions, but also political, social and economic ones. Nevertheless, this paper does not consider the nexus between Kn and Km substitution and socio-economic dimensions.

It is important to stress that projects contain a set of environmental aspects. Considering Figure 2 as a representation of the interactions between economic and environmental systems, two processes are recognized: the input of Knf from the environmental system, passing through projects, to serve the economic production as Kmf, and the disposal of the waste generated both by consumption and production. We will call the first process “extraction” and the second one “injection” of matter and energy in the environment.

Aspects of extraction are typical of projects that deal with direct extraction of natural resources, like mining, wood extraction and fishery. These projects’ goal is to guarantee the flow of Knf from the environmental system to the economic system, directly decreasing total Kn (when there occurs extraction) and indirectly increasing total Km (when Knf is used).

Aspects of injection, by its turn, are presented in all human projects. This process is not accomplished only by projects, but also by the consumption of goods and services that generate flows of waste from the economic system to the environmental one. However, this article focuses only in the regulation of projects. Classic examples of injection are gas and liquid effluent emissions, disposal of high temperature water from reactors and sterile waste pile.

Natural capital is not only substituted by Kmf, but also by Kms (machinery and building). This process is entailed by the economic activity and we will call it “edification”.

Aspects of edification can be characterized by physical structures and are usual is a large development projects, like highways, dams and industrial parks or resorts. Aspects of edification concern the suppression of a certain amount of Kn (affecting both components, Kns and Knf) and consequent implantation of the physical structure, Kms.

Edification and extraction are processes in which natural capital is substituted by man-made capital, while injection is a product of economic activity. In other words, aspects of injection do not configure a phenomenon of capitals substitution.

These forms rarely appear alone. Even a simple project comprehends a wide range of environmental aspects. Projects considered complex are more likely to present various aspects (Glasson et al., 2005; Sánchez, 2006).

Once EIA's forms of impact management aim to change environmental aspects of projects and adjust its general conception, they potentially have capacity to influence the degree in which natural capital is substituted by man-made capital and/or the amount of energy and matter injected in the environmental system.

As already mentioned, prevention is based on the proposition of locational and technological alternatives and it is considered the most effective means of impact management. Each technological alternative comprises a set of environmental aspects. Considering again the example of a road project in a natural forest area and assuming two technological alternatives – overpass and "ground level"– it is possible to list different sets of environmental aspects for each alternative. Suppressing vegetation will be the focus.

Based on the forms of substitution presented in the previous topic, the aspect of suppressing vegetation is related to substitution by edification (forested area, Kn, will be replaced by a highway, Kms). A"ground level" highway will imply the cut of vegetation along the entire road length, while the overpass will suppress only around the foundations. Therefore, the second alternative would reduce the set that compounds the substitution (at least regarding this aspect). In this case, the employment of the alternative avoided the substitution of capital by a process of edification. In other cases, a technological alternative could reduce the amount of waste generated by a project, like when "cleaner" technologies are adopted.

Locational alternatives are conceived observing the Kn to be affected by the project. Taking again the highway example and considering that there would be two possible tracks: one inside of a natural forest area and another inside of grass fields. Considering just these data, the last track will result more substitution of Kn by Kms. The reasoning is justified by the fact that forests are generally considered larger stocks of Kn than grass fields.

Prevention means can also change the substitution by extraction, suggesting alternative dimensions to a mine field or a different location for the axis of a hydropower plant. In these cases, preventive actions would change the rate of Knf extraction and, therefore, its substitution by Kmf.

Thus, the employment of preventive means can both reduce the substitution of Kn by Km and the amount of waste generated by projects that enables economic agents' intentions. So, the preventive exercise can be considered a set of actions that may induce strong sustainability.

It must be stressed that these examples are far from a complex reality. It is hard to understand the intricate network of aspects, forms of capitals substitution and impacts materialized over a specific environment. However, the logic remains.

Adopting or not alternatives that influence capital substitution and/or waste generation, negative impacts will remain. By the rank of impact management effectiveness, the preventive exercise is followed by mitigation actions.

Retaking the highway example, the environmental aspect of oil and other effluent spill on the road will be now the focus. This aspect is part of the environmental aspects' set independently of the alternative arrangement - highway projects always face the risk of potential accidents on the road. Oil or any other effluent spill to the surrounding environment consists in energy and matter injection. There are plenty of mitigation measures to decrease the injuries eventually caused by oil spill.

Mitigation does not aim to avoid impacts but to decrease them, attenuating negative effects generated by aspects already established in the project's overall arrangement. In other words, mitigation measures do not aim to influence the core of the project's productive process, but are planned to be employed just when the project’s production function is already defined. Therefore, mitigation measures do not have potential to regulate aspects of edification and extraction, i. e., capitals substitution.

The exercise of mitigation is focused on those aspects that give support to the accomplishment of the pre-defined production function, remarkably aspects that entail energy and matter injection in the environment, like pollution or waste treatment. So, it can be asserted that mitigation is inefficient in dealing with capitals substitution but it can adequately deal with aspects of injection, inducing weak sustainability when it comes to capitals substitution and strong sustainability when it comes to energy and matter injection.

Finally, the non avoided and non decreased negative impacts can be compensated. The logic that guides compensation is distinct. While prevention and mitigation aim to avoid and decrease negative impacts, compensation aims to find some “equivalent” actions to the lost environmental quality, without changing environmental aspects.

Creating a protected area in the highway surroundings or reserving a percentage of the project’s money for environmental agencies would be compensatory means. So, instead of influencing projects' productive process and outputs, compensatory means promote their exchange by some amount of money. In this sense, compensation can be seen as the very legitimization of both capitals substitution and weak sustainability inducement, especially when it is taken into account that it is "the act of substituting a good for an equivalent one".

In short, we found that prevention would be able to regulate both capitals substitution (by edification and extraction) and injection; mitigation would be able to regulate injection but not to regulate capitals substitution; and compensation would not be able to regulate projects environmental aspects.

4 Conclusion

In summary, the use of environmental economic theories helps to understand how prevention, mitigation and compensation - EIA process - can improve or not the sustainable development, changing the relationship between the economy and natural systems.

The perspective of Kn and Km substitution reinforces the assumption of the EIA theory that prevention has the greater potential to avoid negative impacts and go further. Only prevention has the potential to really change a project’s overall conception and so to influence the production function that generates project’s impacts. So, EIA actions based on prevention (alternative analysis and risk management) has the most potential to improve sustainable development.

Mitigation cannot avoid the substitution of Kn by Km, yet is capable of regulating aspects of injection. Mitigation has a large potential to improve sustainable development, but with some limits.

Compensatory actions, on the other hand, exert no influence over a project’s production function and legitimate capital substitution through the conversion of Kn in some amount of money to be paid by the project’s proponent. In this way, compensatory actions are weak to improve sustainable development. They do not regulate capitals substitution or energy and matter injection in the environmental system. When compensation is applied alone (not following preventive and mitigation means), they give entrepreneurs the feeling that they are adopting means that make their projects more environmentally feasible.

The adoption of an economic approach for the sustainability issue has enabled a deeper analysis of EIA’s capacity to regulate the interactions between economic and environmental systems. It was possible to classify the projects’ environmental aspects according to the way they are related to capital substitution and understand that each EIA’s form of impact management as a different potential to provide environmental viability to projects and different potential do improve sustainable development.

Still, this is a theoretical exercise that seeks to identify the limits of prevention, mitigation and compensation. That is, the article does not examine ways of implementing and operating these actions and therefore it is possible that all forms mentioned may induce weak sustainability depending on how they are implemented.

The Brazilian example given through the contributions of MPU (2004) encourage us to assert that the practice of EIA in that country has not really induced human actions towards sustainability. Therefore, EIA's goals in Brazil have been only partially fulfilled. Its practice has induced actions that follow the neoclassical viewpoint concerning sustainability, i.e., actions that focus on the maintenance of total capital and do not observe natural capital stock levels. We suggest that such an analysis could be applied to other EIA systems in other jurisdictions.

As long as EIA is an environmental policy instrument used to regulate human projects, it is a potential means to control humanity's major way to accomplish the substitution of natural capital by man-made capital, accelerating the global economic system's rate of entropy generation. For further studies, this article can be used as a means to guide the existing policy instruments in a more preventive way, creating new ones within the logic of capitals substitution.

We indicate, thus, that impact analyses could be accomplished taking as reference the stocks and flows of capital used in projects' productive processes in order to evaluate whether natural capital stocks are reduced due to substitution. This proposition generates the new issue of how to quantify these capitals.

Furthermore, a capitals substitution framework (even qualitatively) can be applied to other policy tools analyses, once it enables a better substantiated comprehension of the tools' potential to induce sustainability.

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