Co-operation for the sustainable development in industrial clusters: A Brazilian case study

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Abstract
The purpose this article is to analyze how the firms that are organized in industrial clusters should co-operate for the sustainable practices and operations in the Ecological Economics view. The Ecological Economics theory state that the sustainable development depends on a new paradigm in the form in how the firms organize the system production-consumption. This new paradigm, called by some authors as circular economy, is based mainly on the 4R´s actions and the reverse logistic, not only at the firm level but, mainly, through the value chains. Particularly, the clusters can take a more pro-active role in the circular economy, if their actions seeks not only profits but also contribute for the eco-efficiency and the social equity. In this sense, this article aims to assess clusters in terms of their actions and/or projects related to the principles of the Ecological Economics, especially those whose purpose is to maximize the welfare obtained from economic activity, minimizing the volume of matter and energy which flows through the economy. Such objective is directly related to three basic questions. The first arises when we are concerned to know what criteria can be used to access clusters actions in terms of eco-efficiency. The second derives from the potential trade-off sustainability and profitability and what it means for the clusters´ agents. The last but not the least emerges for those clusters which are interested to know what are the threats and opportunities related to the sustainable development. The methodological approach of this research is based on a multiple case study, analyzing a set of industrial clusters in the Brazilian cities that were mapped in terms of economic activity, localization and historic evolution.

Keywords: clusters, sustainability, strategy

Introduction
The formation of the clusters of firms has been mainly attributed to the fact that the participating companies have more competitiveness through cost reduction, new markets exploitation and technological innovation (Amato Neto, 2009; Iammarino and Mccann, (2006). However, the specific actions aimed at sustainable development has had insufficient attention from cluster researchers as the extent that environmental analysis is a interdisciplinary theoretical field and, on the other hand, such actions

require decisions not only at cluster level but also throughout the value chains, given the systemic nature of the issues to be involved with (Serva, 1992).

In this sense, this paper aims to discuss what the extent the clusters should direct their co-operation to obtain satisfactory results not only in competitiveness indicators, but also in environmental goals. For this, firstly it will be stated the principles of Ecological Economics in order to identify risks and opportunities for clusters which are aligned with the sustainability strategy. Then, in the next sections, it will be shown two analysis perspectives for the role of the clusters in the sustainable development and the framework to assess their actions, projects and plans - A&PP - in terms of their alignment with the Ecological Economics principles. At the end, it will be discussed a Brazilian multiple case study using a recent database to point out how *green* these clusters are.

Principles of Ecological Economics

In the context of the energy crises of the 1970s, the members-countries on the Club of Rome published a report which proposed zero growth as a way to avoid an environmental disaster. Thus, it was created the concept of sustainable development which states that technical progress must respect the environmental limits and that economic growth is a necessary but not sufficient to eliminate poverty and social disparities.

In this sense, the implementation of sustainable development requires, in addition to redistribution of income, the adoption of a standpoint that take into account the inadequacy of the current paradigm of production in terms of the natural resource using and the waste disposal in the environment. Therefore, a new kind of economic paradigm are need, which means the transition from the dominant linear structure to a production-consumption system with cycles according to the 4Rs: reducing, reuse, recycling and remanufacturing.

This optimization of material flow and energy throughout the production-consumption system is the conceptual basis of the Ecological Economics theory to the extent that the anthropic impacts on the environment by the production and consumption activities should be analogous to the working of eco-systems and their natural cycles (Sthael, 2001). To do so, a branch of Ecological Economics thinking, the eco-industrialism (Cohen-Rosenthal, 2003), states practical rules such as the achieving competitiveness with environmental excellence; establishing mutually beneficial connections among and with business, materials, energy, natural systems, markets and local communities and thinking systemically; experiencing locally.

Literature Review

Over the past decades, firms have evolved to behave more pro-active in relation to environmental impacts of their production, since the damage caused by production activities are no longer seen as a matter of cost – as state by the Polluter Pays Principle – to become the main target of the sustainable practices of the entire society (Vinha, 2003; Elkington, 1997). At the theoretical level, this change in the business positions can be understood as the recognition that natural capital and built capital are not perfect substitute for one to another (Daly and Farley, 2004) in the solution of environmental damage and, therefore, corporate governance must be guided by precaution and prevention principles given the irreversibility of the negative impacts of productive activities.

In relation to the environmental issues, this new business commitment has created concepts, criteria and metrics that can be used to assess the extent to what firms should reach the requirements that characterize the Clean Production, such as eco-design (Lewis, 2001), the eco-efficiency, the minimization of environmental impacts, the risk control, the social and environmental audit, accounting and the expansion of the life cycle products. In support of this new form of environmental management by business, Michael Porter (1995) published an article titled Green and Competitive: Ending the Stalemate, which argues that environmental preservation is not a threat to the company, but an opportunity to add competitive advantage.

On the other hand, since the 1970´s many firms and governments have been used for their sustainable solutions the Cycle Assessment Product method (ACP). While ACP can be used by only one firm (Chehebe, 1998; Lewis, 2001) or stage of the value chain, many researchers have been attracted especially for its ability to identify which activities the system between production and consumption are more harmful to the environment (Seliger, 2006).

In this sense, the model for management of supply chains with closed loops – CLSC- have a similar structure related with the production-consumption system of the circular economy mentioned above. To Atasu et al. (2008), CLSC can be defined as "the design, control and operation of a system that maximizes value creation throughout the life cycle of a product from the recovery dynamics of different types and volumes of returned products over time." Therefore, it should be given special attention to the importance of eco-design (Tischner and Charter, 2001) or phase of the product development that will be the subject of remanufacturing, because so many criteria must be observed, among which are included the resistance to wear and ease for identification, separation and handling (Lewis et al., 2001). Thierry et al. (1995), studying the case of a line of Xerox copiers designed for remanufacturing, concluded that this type of product causes a involvement of all departments of the that firm.

How much *green* the clusters are

It will be proposed in this study, as stated below, a framework to classify actions, projects and planning according to the commitment of cluster with the sustainable development in terms of two level categories – horizontal and vertical – and two operation management focus –software and hardware- of these initiatives (see table 1).

Table 1 – Actions, Projects and Plans for Green Clusters

Level versus OM Focus	HARDWARE	SOFTWARE
Horizontal	- Skilled jobs - Environmental technologies - Market of recycled products - Clean Production	- Legislation - Environmental account - Environmental Management System - Legal Agreements
Vertical	- Network of firms - Reverse Logistics - 4Rs Production Chains - ECOPARKS	- Governance - Life Cycle Product Evaluation - Supply Chain Agreements - Database and Information Technology

- The horizontal level versus hardware:

The first set of A&PP aims to guide each firm of the clusters in order to fit its operations according to Clean Production techniques. To do so it is need, at the beginning, to promote investment in physical capital and human power taking into account the Clean Production criteria, which basically means eco-efficiency in the raw material uses and the controlling of waste disposal. In addition, clusters should seek to increase the skilling of workers in relation to new production methods and the use of environmental technologies through the creation of schools, with specific courses, or by revising the current programs of public and private education. Even for the implementation of Clean Production, the clusters should promote innovations projects aimed at reducing negative environmental impacts of their operational activities, such as firms-universities partnership and the creation of specific research centers for sustainable solutions

Another aspect of these A&PP is related to the increasing use of materials and energy taking into accounting the 4Rs. In this sense, clusters should support A&PP that can induce more added value in the post phase of the production-consumption system, which include the diffusion of technologies for increasing the reuse of materials in operating processes and also the creation of channels for colleting and distributing recycled and remanufactured products. At the same time, firms should promote the correct use of their products, providing information on procedures for maintenance and repair appropriate to expand the life cycle of these products and also to reduce energy expenditure in their manufacturing process and throughout their consumption.

- The horizontal level versus software:

The world population is increasingly supporting laws that aim to reduce the harmful effects of productive activities on the environment. Thus, clusters should monitor such national and international laws in order to provide information to companies for planning adequately the need changes in their operational procedures. At the same time, the clusters may offer consulting services, audit and environmental accounting that enable firm-members to participate in more restrictive markets.

On the other hand, member-firms of the clusters should join to public initiatives that aim sustainable solutions for specific proposals, such as educational campaigns to protect animals and forests; the creations of co-operatives of collectors; the maintenance of parks and gardens, among others *green* actions. Similarly, the arrangements of clusters with non-governmental organizations - NGO- contribute effectively to broaden the scope of corporate actions on environmental issues and at the same time strengthen the image of these social actors in relation with the local community.

Finally, the clusters must lead the creation of Environmental Management Systems – EMS – at the level of individual firms (Lustosa, 2003) and also at the level of cluster itself. In this sense, clusters may state common targets for all firms, such as volume of waste; energy consumption and water reused, so that in the medium term the cluster will have firms with the same environmental performance based on those items (Darnall et al., 2008).

- Vertical level versus hardware:

These A&PPs are more challenging for clusters because they are related to a new operational structure that enables the working of the production-consumption system according to the Ecological Economics principles. The fundamental difficulty lies in the fact that firms in the clusters not only belong to several production-consumption systems but also are positioned in different phases of these systems. In this sense, firms in the clusters have to organize value chains in order to create inter-connections with

firms of others regions so that several ways can be built for a continuous flow of energy and materials according to the 4Rs (Beamon, 1999).

To do so, actions taken locally should be combined with vertical business networking so that the results will bring benefits to the local and global environment. Thus, it can be built production-consumption systems through the integration of different firms in projects aimed at the closure of the cycles based on the 4Rs. In these sense, these vertical business can be transformed into Eco-Parks if there is a specific project focused on the concentration of operational activities in a given geographic region. Another important project involving vertical corporate networks and the clusters is the organization and management of reverse logistics supply chains that must operate according with the market working in terms of cost, delivery and distribution (Behrendt, 2003).

- Vertical level versus software:

The A&PP of the clusters in this perspective are strongly related to the implementation of the Cycle Assessment Product – ACP. To do so, it must be built databases with technical information about processes and products to make them available to the public institutions committed with the development of ACP, which involves the integration of firms from different clusters in a single production-consumptions system. Moreover, this new relationship basis must be especially stronger among firms in the clusters and suppliers of the first layer, as the extent that the commitment with targets for Clean Production is becoming a important competitive differential over other suppliers.

On the other hand, factors such as governance (Humphrey and Schmitz, 2000), public regulation and *green* consumers should obligate value chains and clusters to reach targets in sustainability issues that will require change in the firm operational management with any kind of compensatory trade (Sarkis, 2003).

Research Methodology

The framework explained above was elaborated taking into account two broaden theory perspectives. On one hand, it is the cluster analysis, which points out the co-operation of firms as a competitive advantage to reach larger profitability and, on the other hand, it is the Ecological Economics that states the connection between the local firm strategies and the global sustainable development. In this sense, the clusters may be evaluated not only in terms of market performance but also in relation to the effects of the firm co-operation for the circular economy working.

At the same time, the framework in focus can be understood as set of criteria that are required for those clusters which are carrying out A&PP according with the Ecological Economics principles. Thus a multiple case study will properly be elaborated in order to evaluate if some clusters have an actual participation in the circular economy working and how effective are the respective A&PP. As a result it is expected a contribution to enlarge the cluster analysis related to the causes and effects of the co-operation of firms taking into account the environmental restraints. Moreover, this case study should face the following research questions: a) Are the environmental issues strategic for the clusters?; b) What AP&P of the clusters are related to the Ecological Economics principles?; c) What the role do the clusters play in the circular economy working? and d) how much *green* a cluster can be?

Otherwise, for testing purposes, this study will consider a piece of the comprehensive research carried out by *Fundação de Amparo à Pesquisa do Estado de São Paulo* in

which a set of 23 clusters was evaluated taking into account a reference model – i.e. concepts, principles and indicators – especially developed to guide the actions of public and private actors in the promotion/enhancement of such productive agglomerations (Amato Neto, 2009). As a component of this model, the indicators that will be used here are just related to the environmental issues, since the other aspects evaluated are not directly related to the principles operation of the circular economy, as discussed above.

Description of the Brazilian clusters in focus

- City of Sorocaba – sector of machinery and equipment:

The City of Sorocaba stands out for its location: at about 100 km from São Paulo, the largest consumer market in Brazil, has easy access to the Mercosur countries and other cities of southern Brazil, which a hig level of income per capita. The industry of Sorocaba was pioneer in Brazil with the establishment of factories in the textile and food sectors in the late nineteenth century. Nowadays the city is experiencing a strong expansion in the sector of machinery and equipment, and auto parts as a result of new investments, especially those related with the first Toyota plant in Brazil. This cluster, therefore, is formed by small and medium-sized industrial firms in the metal-making machines and mechanical equipment to meet the demands of automotive and electrical sectors. Such firms are specialized in several production processes for the production of capital goods: maching, stamping and tooling calderaria. This combination of expertise results in a broad range of productive resources to the sector of machinery and equipment, which makes this attractive city for investments in several industrial sub-sectors.

- *ABC Paulista* Region – processed plastics industry:

The characterization of ABC Paulista Region while the automotive hub of Brazil has been revisited in recent years by social actors in this region due to the rearrangements occurring in the organization of production of local firms as well as the adverse effects of macroeconomic policies aimed at combating inflation and reducing public debt. From these discussions among local institutions, the development of processed plastics sector was appointed as an alternative to the dependence on local economy in relation to the automotive industry in terms of generating employment and income. This diagnosis is due to the fact that this region also has a concentration of petrochemical industry which supply inputs to the firms in the plastics manufacturing cluster, i.e. the two main production links of de production chain are in this region and, therefore, there is a large potential for economies of agglomeration. This cluster became a priority for the actions of local governments in partnerships with several institutions such as state and federal governments. The presence of the auto industry, in particular, justifies such priority, since the firms which produce processed plastic form on key suppliers to this industry.

- City of Limeira – manufacture of costume jewelry:

The origin of industrial activity in this city is closely related to the manufacture of farm machinery in the early twentieth century. In the last three decades, the industry of gems and veneers, which production processes has similarity to production machines, gained prominence in the generation of employment and local income. This cluster is composed of both large firms that outsource services of assembling and welding, as by specialized firms that are suppliers of raw materials and belong to a same group. Moreover, there is still a universe of small firms that lack the industrial plant for their own activities and are inserted in a productive network outsourcing, from which obtain inputs and sell their final products. Given the characteristics of the production process

of veneer, there are in the region a number of environmental problems, caused mostly by chemicals used in these productive activities.

- The Santa Gertrudes Region – manufacture of ceramic coating:

The productive arrangement of Santa Gertrudes region had its beginning as an important producer of tiles due to the following competitive advantages: local availability of raw materials and proximity to the main consumer market of Brazil. Nowadays, the region has about 37 firms whose ceramic products are sold to all regions of Brazil. This cluster is characterized by small and medium firms which together account for 80% of total firms, none of which has the participation of foreign capital. The most important advantages of the Santa Gertudes region are: proximity to major consumer center in the State of São Paulo, high availability of raw material and easy access to highway transportation. Moreover, new strategies for competition become gradually priorities of these companies, such as product differentiation, improved quality, service delivery times and increased exports. Then, the cluster is undergoing a transition moment: while the price remains a means of competitive advantage, other characteristics emerge to improve quality of the products in order to obtain certifications and higher exportations from the business of the region.

Database used

Before the results presentation, it is briefly described the indicators of the reference model mentioned in the section 5. Such indicators are related with the evolution of the clusters, particularly highlighting the following aspects: socio-economy, technology, institutional supporting, environment, governance, globalization and managerial training. In the table 2 presented below, each of these aspects is related to the respective variable.

Table 2 – Reference Model: indicators and variables

Indicators	**Evaluated variables**
Geographical	Raw materials, consumers, infrastrcture and population
Economic Competition	Competition, integration, cost, capital and consumer markets
Institutional	Degree of formalization and support networks
Social	Formal education of the work force
Technological	Education, external tehcnology, development and quality
Environmental	Water, air, waste and consciousness
Governance	Leadership, local presence of an active agent and degree od legitimacy
Internationalization	Internationalization exports, direct investment and participation in international fairs
Training mangement	Production, financial, commercial and people management.

The calculation of the indicators listed above was based on questionnaires sent to firms in the clusters. Data obtained for each indicator were classified according to a score that could take the values 4,3,2,1 or zero. Individual indicators of one aspect were compared and assigned a value equal 1 for the minor, 2 for the important e 3 for the very important. For the calculations of global indicators, the evaluation of cluster in relation to the aspect examined was considered a weighted average of individual indicators by their respective weights. The list with the abbreviation code of the indicators used in the evaluation of the cases studied is showed in the table 3.

Table 3 – List of Indicator Code

Geographic and Global Geographic	IG e IGG
Economic and Global Economic	IE e IEG
Institutional and Institutional Global	II e IIG
Social and Global Social	IS e ISG
Technological and Global Technological	IT e ITG
Environmental and Global Environmental	IA e IAG
Internationalization and Global Internationalization	IInt e IIntG
Governance and Global Governance	IGov e IGov
Manager Capacity and Global Manager Capacity	ICG e ICGG

The set of environmental indicators is to evaluate, basically, the major adverse impacts to the ecosystem of the region caused by the productive activities of a given industrial cluster. It also seeks to identify whether there are actions undertaken to greater environment awareness in firms and the local population. The table 4 below list the aspects evaluated with their environmental indicators.

Table 4 – List of Environmental Indicators

Identification	**Evaluated Aspect**	**Indicator**
IA1	Water Supply and Sewerage	Firms are served by water and sewer?
IA2	Emission of pollutants in water	Firms perform some type of emisson of polluting the water?
IA3	Sewage treatment	Firms develop some type of sewage treatment?
IA4	Capture rain water	Firms seek to capture rain water?
IA5	Emission of air pollutants	Firms perform some type of emission of air pollutants?
IA6	Treatment of air pollutants?	Firms perform some type of treatment the emission of air pollutants?
IA7	Use of recycled raw material	What is the rate of use of recycled raw material in relation of the total volume of material used?
IA8	Selective Collection	Firms develop some kind of selective collection of waste produced by them?
IA9	Production processes that generate dangerous waste	Firms operate with any kind of production process that produces dangerous waste?
IA10	Activities of environment preservation	Firms do, in a systematic way, some kind of environmental preservation in the community?
IA11	Existence of institutions dedicated to environmental conservation	Are there organizations to promote environmental conservation in the region?

Presentation and discussion of the results

For each of the clusters describe above, it was calculated indicators for all the aspects and then these indicators were arranged as the following;

Table 5 – Indicators Results for the Selected Clusters

City/Region	IGG	IEG	IIG	ISG	ITG	IAG	IIntG	IGovG	ICGG
Sorocaba	2,71	2,79	1,83	2,88	2,40	2,42	1,44	2,50	2,00
St. Gertrudes	3,06	2,46	2,89	2,75	2,80	2,58	1,56	1,38	2,80
Limeira	2,76	2,86	2,17	1,75	1,47	0,73	1,22	1,38	1,10
ABC Region	3,53	2,58	3,11	3,13	3,89	2,00	1,22	3,25	2,80
Average	**3,01**	**2,67**	**2,50**	**2,63**	**2,64**	**1,93**	**1,36**	**2,13**	**2,18**

It initially must be noted that the environmental indicators has only partly relation to the classification proposed in the framework present in the section 3, since the database were elaborated not only for environment issues but also for evaluating other relevant aspects of the development stage of the clusters in the State of São Paulo. Thus, all environmental indicators identified in table 4, except for the IA 10 and IA11, are related to the field of A&PP in the horizontal level versus hardware. At the same time, indicators IA 10 and IA 11 are in the field of A&PP horizontal level versus software, which shows the limitation of the results for the evaluation of environmental aspects in other possible fields of action of clusters on the circular economy.

However, given this constraint, the results permit a basic assessment of clusters with respect to environmental issues and at the same time, conduct a comparative analysis with other aspects and also with environmental aspects of the other clusters. In this sense, it can be observed that the cluster of Santa Gertrudes region attaches great importance to the environmental impacts of their production processes, while the cluster in the City of Limeira, due to the feature of their activities, has serious challenges for the integration of their firms in a agenda for sustainable development. On the other hand, it should be noted that none of the clusters evaluated hit the 4.0 top score in global environmental indicator, suggesting that there is a great way to be followed by firms in these clusters in order to contribute to reduce negative environmental impacts of their activities.

Finally, the results show that the achieving of internationalization of clusters and reducing the environmental impacts of theirs activities are among the objectives that need more effective A&PP, which it is perhaps just a reflection of what happens at the firm level strategy, where most of them have focused only on domestic market and moreover they are still trapped in the trade-off between profitability and sustainability, as mentioned before.

Conclusions

Clusters can play an important role in global advocacy for sustainable development. To do so, it is necessary that the actions, projects and planning of these organizations are geared not only to profitability but also for social equity and the preservation of the environment. In this sense, the strategies of the clusters should seek the combination of their activities so that instead of having a trade-off profitability and sustainability, the results are mutually beneficial. These strategies are justified to the extent that investments in Clean Production will create competitive advantages in a dynamic world economy where consumers are increasily aware of environmental issues and the laws become more restrictive to those companies who harm the environment.

Thus, the clusters should serve as a catalyst for initiatives aimed at sustainable development that occur both at the corporate level and throughout the value chains. Such actions, according to the principles of Ecological Economics, will cover activities for the implementation of Clean Production and sustainable consumption-production system from the standpoint of energy and material. Some actions in this direction have been discussed here as a proposition for future research, among which it should be highlighted the creation of environmental consultants for firms in clusters, the elaboration of databases for assessing the Life Cycle of the Product, and deployment of Environmental Management for both firms and either clusters.

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