Sustainable development and productive cooperation: a petrochemical–plastics industrial cluster case in the Grande Abc Paulista region, Brazil
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Abstract

The economic benefits brought by the structuring of industrial clusters in various regions of the world may also contribute to the adoption of practices for social and environmental dimensions of sustainability. Taking into account an environmental dimension, industrial clusters can develop, from a systemic perspective, joint actions for waste reduction and savings in consumption of raw materials and energy, with positive results for both the local environment and, especially, for the various stages of the products life cycles. Considering this, the case study of the petrochemical-plastics industrial cluster in the Grande ABC region, Brazil, showed two opposite situations throughout its evolution.

Keywords: sustainability, industrial clusters, cooperation

Introduction

Over the past decades, a growing number of companies are adopting proactive strategies rather defensive about the environmental impacts of its production activities, as the Polluter Pays Principle, under which the establishment of a price induces the pollutants to lower their evictions in the receiver body to prevent the collection of service (Canepa, 2003) became unworkable front the growing size and complexity of the main environmental demands of the whole society (Vinha, 2003). This change in corporate attitude can be understood as a recognition that natural capital and manufactured capital (Ekins et al., 2008) are not perfect substitutes for each other (Romeiro, 2010) so that business strategies should be guided by the principles of precaution and prevention, given the irreversible nature of many negative impacts of productive activities. Prevention occurs when actions are performed according to estimates of future problems, while the adoption of the precautionary principle (Furtado, 2005) is with actions before a potential source of problems, without waiting to available scientific certainty about the causal relationship between an event or activity and the dreaded problem.

This performance of companies with strategies that seek not only as the increase in financial results, but also take into account social and environmental responsibility of their activities, is now accompanied by triple reports results, or triple bottom line, from
which the companies will increasingly be assessed for their social and environmental performance and financial results, due to the new requirements demanded by social actors (stakeholders) in relation to the sustainability of productive activities (Elkington, 1997; Da Silva and Quelhas, 2006; Zilber et al., 2011). However, many of these indicators are systemic, or are related to the environmental impacts derived from the activities carried out throughout a supply chain, such as the analysis of the product life cycle (Seuring, 2004; World Economic Forum, 2014). At the same time, there are indicators (consumption of drinking water, employment, deforestation) that refer to the consequences of productive activities on a region, such as the use of natural resources, job creation, among others.

Thus, the performance of each company depends on the environmental management of networks or groups of companies, whether they are considered the results of regional or sectoral indicators, implying the need to build a governance structure capable of integrating the individual contributions due sustainable development (Matos and Hall, 2007). In the absence of an institutionalization of such environmental management agglomerations and / or supply chains, many companies began to perform countermeasures (Pereira et al., 2011) as requiring suppliers certifications, strict compliance with environmental legislation, the creation networks of local entrepreneurs, among other initiatives aimed at reducing the systemic risk associated with all productive activities (Atasu et al., 2008).

Literature review
Sustainable development or sustainability should be on the agenda of the whole society in the coming decades. Although based on ethical considerations and justice, the concept of sustainability and the construction of the indicators showed higher awareness of the company over the limits of the current paradigm of production and consumption, leading to the realization of social and environmental practices by companies. These, in turn, when making connections and relationships with each other and with other social actors who provide the closing cycles in supply chains (Matos and Hall, 2007), are contributing decisively to the balance between human activities and the environment, according to the precepts Ecological Economics and Industrial Ecology as we see below.

The Ecological Economics (EE) was consolidated in academia over the decade of 80. It is a regular discipline of economics to rescue a historic debt of economic thought related to the role of natural resources in their theoretical constructs (Cechin and Veiga, 2010). Unlike Malthus, Smith, Mill and other classical economists, who showed the importance of considering environmental aspects in the development of economic theories (Perrings, 2008), especially those related to the growth of production and consumption, almost all the leading economists of nineteenth and twentieth centuries considered true the hypothesis that the scarcity of natural resources in the long term, not a barrier to productive activities. Contrary to this dominant view in most schools of economic thought, the authors of EE (Daly and Farlay, 2004) recovered the classical tradition and brought to the center of the debate issues such as the interdependence of the economic system and ecological balance, given the trend reaching the limit of biocapacity of the planet Earth, maintaining the current rate of consumption of natural resources.

So while the EE analyzes the co-evolution of economic and ecological systems to describe scenarios from which social actors can anticipate the crisis and conduct countercyclical measures, another approach to sustainability, ecology Industrial, adopts biological cycles as an analogy to show the way that the productive and consumption
activities should follow, taking into account the balance of ecological systems. Therefore, EI clearly assumes the validity of the assumptions stated by EE for the environmental impacts of the economic system and proposes a systemic approach that integrates production and consumption processes, considering the reduction perspective on the use of natural resources and minimizing the generation of residues.

In this sense, EI can be defined as the study of flows of materials and energy and the stages of its transformation into products, by-products and waste along the chain of production and consumption (Chertow, 2000; Ayres and Ayres, 2002). This primary definition more systemic perspective of ecology associated with the complexity of community organization defines the conceptual basis of EI in a broader sense. Therefore, the EI also seeks to identify and propose models of sustainable relationships between producers and between them and the natural ecosystems (Cohen-Rosenthal, 2003).

Moreover, each of these subjects may be grouped into a framework according to the following operating domains EI: company, interfirms, regional and global business and clusters (see Figure 1). Thus, it can be identified and differentiated elements of EI that rely on individual initiatives, such as sustainable product design (Seuring, 2004), and those that are related to joint actions of companies in a sector and / or geographic area, as is the case the construction of industrial ecoparks (IEP) and collective actions of local production systems (LPS), we will see in the next sections.

![Figure 1 - Model reference of Industrial Ecology](image)

**Industrial ecoparks as a reference to the LPS**

LPS can arise both through market relations as in the midst of public projects for local development. Similarly, the most successful cases of IEP in the literature belong to the spontaneous self-development group, in that it did not arise as a result of implementation of public policies, but rather the formation of connections between companies aimed at receiving economic benefits (Neves et al., 2011; Taddeo et al., 2012). There are IEPs in various countries such as USA, China, India, Canada, Germany, Italy, Australia and Austria, and the most prominent example in the literature
is located in the city of Kalundborg, Denmark (Barros and Rosa, 2011). The Kalundborg EPI, as it became known, developed from the problem of water scarcity they encountered the various activities of the municipality, such that, around a thermoelectric, docked-a myriad of connections; from the production of fertilizers to the energy supply in local housing, including through the supply of gypsum to produce slates.

Taking as reference the form of integration of productive activities, the LPS can coordinate and catalyze oriented business initiatives for sustainable development because, when dealing with complex systems, are possible new institutional and production arrangements that seek results in the three dimensions of sustainability (economic, social and environmental). Therefore, the social actors and companies should position themselves proactively in relation to possible evolutionary trajectories of LPSs in which they live because, without a dedicated governance for sustainability, there is a tendency to avail the business as usual of conventional economics.

In this sense, the collective actions of LPS should advance to the productive integration and the establishment of institutions that promote "a set of long-term symbiotic relationships between local productive activities involving physical exchange of materials and energy as well as the exchange of human resources, technological and knowledge, continually promoting competitive, social and environmental benefits" (POSCH, 2010). These symbiotic relationships are specified as follows: material recycling and energy reuse; cooperation for improvement and integration of production processes; cooperation in the development of sustainable products; adherence to a common social responsibility and promotion of cross-company learning and knowledge generation.

The role of the LPS in sustainability

From the economic benefits brought by the formation of local production systems (LPS) in various regions of the world (Belussi, 2005; Amato Neto, 2009) it is possible to assume that such organizations have characteristics that also contribute to the adoption of practices for social and environmental dimensions of sustainability. In this paper will be used the terms "local production systems", or just LPS, as a reference to all possible shapes and stages of development of productive agglomerations. The various existing LPSs have common characteristics, such as the territorial proximity between social actors, the type of productive activity performed, the availability of support services and other positive externalities. At the same time, the LPS stage of evolution also depends on interactions between social actors and governance of collective activities focused on innovation and sustainability.

The LPSs are determined, according to the systemic and complex view (Morin, 1996; Checkland, 2002) both for its structural characteristics as the quantity and quality of interaction between social actors (Matos and Hall, 2007). That is, the results of the activities of LPS depend not only on the configuration of their geographical and productive characteristics, but also the performance of local social actors. In this sense, the LPS can also be identified by the role and participation of several institutions, local or not, in the projects and developed collective action. From these general features, case studies (Belussi, 2005; Amato Neto, 2009) have shown a wide range of industrial agglomerations with peculiarities and idiosyncrasies that link new aspects and perspectives relevant to understanding the origin and development of LPS. This paper considers these studies to assume that certain constitutive and organizational factors of LPS may have the ability to act proactively in activities for sustainable development site
in the same way that contributed to the increase in income and employment in many regions where were consolidated.

As for the social dimension, the LPS can promote and practice, from the accumulated capital, ethical values, and develop and disseminate the culture of participation and cooperation, resulting in behaviors that respect human rights and value work, especially based the principles of corporate social responsibility. To corporate social responsibility is attributed human characteristics to business activities, because it is expected that there is an ethical commitment of companies for social and environmental sustainability. In this sense, companies began to consider important decisions sharing with stakeholders, to the extent that the risks associated with productive activities do not depend solely on technological solutions but also institutional changes negotiated between the actors to avoid or deal with situations critical, as the destruction of ecosystems and slave labor (Matos and Hall, 2007 and World Business Council for Sustainable Development, 2010).

By the environmental point of view, the LPS can develop, from a systemic perspective, joint actions for waste reduction, consumption of raw materials and energy, with positive results for both the local environment and, especially, for the various stages of the life cycles of end products that are partially or wholly produced locally (Wallner, 1999). In this sense, one of the main challenges to both business and public managers and other social actors of LPS, is the establishment of a governance to propose and conduct collective actions aimed not only to increase the competitiveness in the markets, but also to meet social and environmental responsibilities for sustainable development (Deutz and Gibbs, 2008).

It is, therefore, to adopt shared strategies to address issues such as the disposal of waste generated by LPSs, the reduction of energy use and raw materials and the transition to a low carbon economy. In this scenario, the smaller the use of new raw materials will lower the generation and the cost of waste disposal. In a mature low carbon economy, consumers exchange much of the ownership of physical assets by providing services and companies, in turn, come to control production processes and share the equipment and their environmental costs (United Nations Environment Programme 2010; Sthael, 2001).

Case Study: Petrochemical Plastics LPS in GABC and sustainability
Companies of plastic processed have few options for other competitive strategies, beyond based on prices. Companies in this petrochemical plastics LPS segment are in the same competitive position that most of the companies processed plastics in Brazil; interspersed between powerful oligopolies both downstream of the production chain (automotive, food industry, wholesale networks) and suppliers (petrochemical industry), and exercising the function of quasi-industrial service providers.

The type of end user, in turn, implies different relationships between customers and producers, enabling technological strategies based on different vectors of training and skills. On the demand side, the following options are presented: reach final consumers (marketing, branding, product differentiation, design, reducing environmental impacts and recycling) or seek final consumers (new solutions, substitute materials based on the advantageous properties plastic, deadlines, economies of scale, economies of scope, quality and compliance, value added.

To J. E. Cassiolato et al. (2005), companies in the petrochemical-plastic chain GABC form an "arrangement" and not a "system" innovative and productive place as the innovation process occurs in isolation and without the participation of relevant stakeholders. At the same time, addressing productive agglomerations made by S.
Iammarino and P. McCann (2006), said production chain has the characteristics of an industrial cluster, since, among other things, the activities related to research and development of products and processes are carried out internally in leading companies with a high degree of expertise and respecting the hierarchical bureaucracies.

**Methodology**

The petrochemical-plastic LPS in GABC region was selected for the study of emerging practices in LPS in an interdisciplinary and systemic perspective, since the social and environmental aspects in productive agglomerations have been, so far, little explored in the literature. At the same time we seek with it the realization of interfaces with other disciplines through the use of concepts belonging to the Industrial Ecology and Ecological Economics.

<table>
<thead>
<tr>
<th>Table 1 – Reference model with research variables</th>
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<tr>
<td><strong>1º. Phase: connections (loops in production processes and consumptions)</strong></td>
</tr>
<tr>
<td>Connections</td>
</tr>
<tr>
<td>Material recycling and energy reuse</td>
</tr>
<tr>
<td>Cooperations for improvement and integration of production processes</td>
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**2º. Phase: network focused on industrial symbiosis**

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<th>Colletive acion</th>
<th>Variables</th>
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<td>Cooperation for the development of sustainable products</td>
<td>- SLP’s strategies for sustainability</td>
</tr>
<tr>
<td>Adherence to a common social responsibility</td>
<td>- Individual or collective environmental responsibility</td>
</tr>
<tr>
<td>Promotion of cross-company learning and knowledge generation</td>
<td>- Governance structure of LPS for sustainability</td>
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<td></td>
<td>- Sustainability indicators of LPS</td>
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This case study is based on the reference model mentioned in Table 1. In it, show up two phases of evolution by which the LPSs must pass for their actions, programs and collective projects are aligned with the three dimensions of sustainability (economic, social and environmental). The first phase refers to the establishment of own-company connections directed to the reuse of materials and energy; and the second concerns the measures related to cooperation in a comprehensive manner, in several class actions, projects and activities. Therefore, the field of research has focused on collecting evidence pertaining to each phase and identifying the evolutionary phase of the LPS.

With respect to the properties of LPS associated with sustainability, particularly, it is possible to assume that there is a process of self-organization triggering forms of collective action aimed at increasing the productive, social and natural capital. In this sense, the above reference model above will be used to assess the constituent and organizational factors in the petrochemical plastics LPS in GABC region that act as catalysts in this process. This model of "two phases" of development of LPS, was appropriately transformed to contain the search variables based on POSCH’s model. The field research, in turn, is divided into two parts of different natures. The first part refers to the collection of information on the social actors in the petrochemical industry.
and the second refers to a set of interviews addressed to an intentional panel of social actors related to transformed plastics industry in the same region. It is observed that, as such, it is used two subsets of sources of information on the development of the petrochemical plastics in GABC region.

**BOX 1**

**Synergy Group (APOLO)**

In the publication "The history of the Greater ABC Petrochemical and Apolo", Klein (2011) gives a detailed account originated by statements, publications in the form of books, periodicals, catalogs, theses and websites of the key moments in the history of companies of the first and second generation petrochemical complex of GABC. Referring to these times, three moments can be considered critical: the initial, when the creation of the Union Petrochemical Company was supported; the second with the loss of the period of competitiveness of all companies in the second half of the 90s; and the productive capacity expansion phase of these companies over the years 2000. Thus, in the midst of a crisis of the Brazilian petrochemical industry, in particular in the Greater ABC, the Synergy Group arises to create a new business format. At this point of view, it is showed that collective actions implemented by this group of entrepreneurs reached the following triple bottom line results: reduced operating costs, expanding by 40% of the production capacity of the petrochemical complex of GABC, building a positive image among civil society GABC, carrying out activities together with the local community, and overcoming environmental constraints on the activity of the petrochemical industry. In 2004, the Synergy Group became the Apollo (Association of Polo Petrochemical Industries of Greater ABC) which, until its dissolution in 2012, continued to make significant collective actions, among which stands out the coordination of community centers civil defense and community collection network for edible oil recycling.

**Aquapol Project**

The issue of water supply for companies in the Petrochemical Complex of GABC has always been strategic, both from the point of view of the activity itself, which is intensive in this resource, such as the fact that the region of Greater São Paulo, where lies the GABC has one of the largest urban populations in the world and therefore has a high demand on regional water resources. So when it started technical studies to determine the feasibility of increasing the production capacity of the petrochemical complex of GABC, it was proposed the construction of a 17 km aqueduct, connecting the cities of São Caetano do Sul and Maua, for the transport of water for industrial use or reuse water. The realization of this project, called Aquapolo directly involved social actors in three municipalities of GABC until it was completed in 2012, through public-private partnership between Braskem and Sabesp company. Currently, reuse water meets all the demand of the Polo Petrochemical GABC and is still offered to companies in the region, at a lower cost to the drinking water. By not consuming (and therefore available) thousand liters of drinking water per second, companies and other actors of the Greater ABC region, and especially those of petrochemical-plastic chain, have succeeded in carrying out joint actions, aimed at obtaining positive results in the three dimensions of sustainability (economic, social and environmental).

**Presentation of results**

In the first part, therefore, the purpose of archival work is to point organizational emergencies that occurred in the wake of recent developments in petrochemical-plastic LPS in GABC and which are listed in the reference model proposed as "connections"
and / or "collective action". Thus, we reached two experiences that are described in BOX 1.

Table 2 – Social actor’s considerations regarding sustainability in the LPS

<table>
<thead>
<tr>
<th>Actions of LPS related to the principles of Ecological Economics and Industrial Ecology</th>
<th>6 social actors mentioned directly or indirectly such actions. Of these, 02 responses were selected by the strong approximation to the principles of EI and EE. In multiple choice questions, we highlight the items &quot;recycling and 4R&quot; and &quot;use of by-products&quot;.</th>
</tr>
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<tbody>
<tr>
<td>Green managerial practices as 4R’s, among others.</td>
<td>As the manufacturer of recycled raw materials pointed out important aspects of recycling activity, although the item &quot;recycling and 4R&quot; as well have been the most practiced, also appears among those items that most will practiced in the coming years, as the answers to the multiple choice questions.</td>
</tr>
<tr>
<td>Actions of LPS focused on sustainability</td>
<td>Among the 08 players who made references to such actions, there is the informant of ADE, which quoted a kind of &quot;early warning&quot; to the auto parts market. Most of the answers to the multiple choice questions, there is the presence of many activities of circular economy through the items: &quot;use of recycled raw material&quot;, &quot;generation of by-products or waste&quot; and &quot;follows the precepts of cleaner production&quot;.</td>
</tr>
<tr>
<td>Strategies of LPSs in relation to sustainability</td>
<td>Both a reactive posture (&quot;legislation and cost are what drive the actions&quot;) and proactive (&quot;leverage sustainability projects&quot;, &quot;create a complex and economically viable structure&quot;) were observed. Among the actions for sustainability that more should be practiced in the coming years, the items appear &quot;clean production&quot;, &quot;recycling and the 4 R's&quot; and &quot;skills and employability of labor.&quot;</td>
</tr>
<tr>
<td>Individual environmental responsibility and / or collective</td>
<td>Although most social actors (08 panel) was observed in relation to this issue, only the professor was more objective in stating that &quot;everyone involved in the project have their share of responsibility.&quot; In various forms, the &quot;act collectively to confront the issues related to sustainability&quot; was often cited.</td>
</tr>
<tr>
<td>Governance structure of the LPS for sustainability</td>
<td>The 06 spontaneous responses obtained relate to the governance of LPSs in general and not specifically to the treatment of sustainability. However, all answers can be taken into account because it was explained that the interview subject was &quot;APL Plastics GABC and sustainability.&quot; The governance of LPS petrochemical-plastic GABC, according to the informants, is multipartite character (social actors), as is reference in the phrase &quot;the companies themselves and the 'big players' in the industry, with the participation of supporting organizations and governments.&quot; In addition, this governance should integrate different interests: timing, market (cooperation versus competition), segmentation (packaging, auto parts, construction) and corporate structure (production capacity and technological development).</td>
</tr>
<tr>
<td>Sustainability indicators of LPS</td>
<td>Many of the manifestations of the informants were favorable the indicators given in the &quot;tips&quot; that comprise the questionnaire body. It is noteworthy, however, the mention of specific recycling and reuse indicators for plastics.</td>
</tr>
</tbody>
</table>
In the second part, we try to verify the perception of social actors in relation to the constituent and organizational factors of petrochemical plastics LPS in GABC over recent developments, according to the variables of the reference model. The results are shown in Table 2.

**Conclusion**

The data and information presented show the phases in which the petrochemical-plastic LPS in GABC has evolved through the phases 1 and 2 of the reference model, setting a system expansion where the establishment of connections and conducting collective action was crucial but that, in the current scenario, remains more a function of the results achieved than by the existence of joint activities related to the principles of Industrial Ecology and Ecological Economics. The results of the first part of the field research, therefore, are associated with this current scenario, where local actors are keen to resume collective action as a strategy to solve common environmental issues, but adjustments are needed in the way projects are designed, developed and realized.

From another perspective, the expansion of the productive capacity of the Petrochemical Complex of GABC generated income and local employment and at the same time reduced the emission of pollutants, as amended legislation after performance of the Synergy Group. Such actions, among others, show the involvement of all social actors, including the plastics processors in collective actions for sustainability. In this sense, the LPS GABC petrochemical-plastic presented at this stage both the connections of the 1st. phase of the reference model (activity related to loops in the production process and consumption) as the collective actions of the 2nd. phase (network focused on industrial symbiosis).

However, in the current scenario, this accumulated capital in the form of collective action appears to be dispersed, as businesses and other social actors perform various activities related to circular economy, among which are the recycling and the use of by-product in the processes productive but show themselves unhappy with the results.

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**References**


